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A DESCRIPTION

OF THE

FIRST OR ASWAN CATARACT

OF THE NILE

By

JOHN BALL, Ph.D., B.Sc., F.G.S.

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FIRST OR ASWAN CATARACT OF THE NILE

CHAPTER I.

INTRODUCTORY.

GENERAL NATURE OF NILE CATARACTS.

At intervals along the upper portion of its course the Nile has cut its way through hard masses of igneous rocks which crop out amongst the softer sedimentary formations. In some cases, where the igneous rocks are so crushed as to offer, in spite of their hardness, comparatively little resistance to erosion, or where erosion has gone on so long as to have removed the rocks sufficiently to give a clear passage, the river traverses these areas without disturbance, though its channel is locally narrowed and shut in by steep escarpments. At other points, however, the hard igneous masses form natural barriers, often many kilometres in length, in the river's path, maintaining the water at a high level above them and causing the formation of numerous rapids in the narrow channels into which the river becomes split up in its descent. The rapids thus produced, when of a certain magnitude, are called "cataracts," and are numbered in order upstream, the cataract of Aswan being called the First, that of Wadi Halfa the Second, and so on.

Forming as they do a formidable hindrance to the navigation of the river, the periodic rise and fall of which introduces an additional element of difficulty by totally altering the distribution of water in the various channels, the Nile cataracts have naturally acquired in the commercial world of Egypt a reputation which they are far from meriting as waterfalls. There is nothing about a Nile cataract in any way resembling Niagara, nor even the Falls of the Rhine

at Schaffhausen. The total fall of the water-surface at the First Cataract (between Philæ and Elephantine) is only about 5 metres in a length of about 9 kilometres; and although the greater portion of the fall is concentrated within a fraction of this total length, it is only sufficient to give rise to rapids, and not to a waterfall in the ordinary sense of the term. The obstruction to navigation offered by a Nile cataract is in fact due, not so much to the velocity of the water, as to the irregularity and conflicting nature of the currents caused by the narrowness, winding courses, and rocky state of the channels.

Position of the First Cataract.

Aswan, the chief town of the most southern province of Egypt, lies on the east bank of the Nile, very nearly on the site of the ancient Syene, at the foot of the First Cataract. Its latitude is 24° 5′ 18.5″ N., and its longitude 32° 53′ 26.7″ E. of Greenwich,* while its altitude above sea-level is about 90 metres. Aswan is distant about 900 kilometres by river, or 882 kilometres by rail, from Cairo, and express trains perform the journey in about twenty-one hours. The *First Cataract* occupies about 2½ kilometres' length of the river, and ends about 4 kilometres south of Aswan; but it is convenient to include in the Cataract district all that portion of the river which is beset with islands, viz., from the south of El Hesa Island to the north of Elephantine, together with so much of the desert on either side as is possessed of settlements, roads, and archæological remains. Thus the district to be described in this memoir has a total length from south to north of about 13½ kilometres, and a maximum width from west to east of about 8 kilometres.

History of the Cataract District.

There are few districts, even in Egypt, of which the history can be traced so far back into the remote past as that of Aswan. Its tombs form an important source of our knowledge regarding the sixth dynasty (about 3,500 B.C.), while among its rock-inscriptions

* The precise point for which this position is given is the Roman ruin commonly known as "Cleopatra's Bath," on the east shore of the Nile about opposite the centre of Aswan.

and other antiquities are found records of almost every succeeding dynasty, as well as of Ptolemaic and Roman times. And in addition to having a long history of its own, Aswan can boast of having furnished the material on which much of the history of Egypt in general is engraved; for from the days of the great pyramid-builders onwards to our own, the red-granite quarries of Aswan have been worked at intervals for monuments and buildings of importance.

Abundant as is the material, any attempt at a connected history of the Cataract district is beyond the scope of this memoir. The principal historical facts will however be briefly referred to in describing the topographical features with which they are associated, and the reader who desires further details should refer to the historical works, of which a list will be found on pp. 15—20.

The Relation of Aswan (Syene) to Ancient Geography.

In his famous attempt to determine the size of the earth (about 230 B.C.) Eratosthenes * employed Syene as the southern extremity of his meridian arc, the northern station being at Alexandria, and from the importance of this investigation Syene at once obtained a prominent place in geography. The method used was to determine (1) the difference between the zenith-distances of the sun at Alexandria and Syene at noon on the day of the solstice by means of the shadow cast by a gnomon set in a hemi-spherical bowl or "scaphe," thus obtaining the difference of latitude between the two places; and (2) the distance between them in stades. From a comparison of these two values, the circumference of the whole earth could be computed by simple proportion. Eratosthenes found that while the gnomon at Syene on the day of the summer solstice cast no shadow, that at Alexandria cast one subtending one-fiftieth of the circum-

* Eratosthenes was born at Cyrene about B.C. 276; he was invited by Ptolemy Euërgetes from Athens to Alexandria as keeper of the library. His treatise on geography, in three books, has been lost, and we derive our knowledge of his work from later writers, such as Cleomedes, Strabo, and Pliny. Prior to the time of Eratosthenes, attempts had already been made to solve the problem of the earth's magnitude (v. ARISTOTLE, "De Coelo," 2.14.16); but little is known of them, and the results were grossly inaccurate. For a full account of the works of the Alexandrian geographers the student may consult BUNBURY's "History of Ancient Geography"; or TOZER's "History of Ancient Geography" in the Cambridge Geographical Series; or BERGER's "Geschichte der Wissenschaftlichen Erdkunde der Griechen."

ference of the "scaphe." * Taking the distance between the two places as 5,000 stades, he calculated the circumference of the earth to be, therefore, 5,000 $\times$ 50, or 250,000 stades.†

The sources of weakness in Eratosthenes' determination were the roughness of the angular measurement, the approximate nature of the distance-estimation, and the falsity of the assumption that the two towns were on the same meridian. A gnomon of moderate size would cast no perceptible shadow at the solstice even twenty miles from the tropic. The distance appears to have been determined by the time occupied in voyages between the two places; and though allowance seems to have been made for the windings of the river,‡ the corrected result can only be roughly approximate. Lastly, the difference of longitude between Alexandria and Syene is more than 2°. Nevertheless, the result obtained was surprisingly near the truth, and the determination was justly regarded as a great achievement for the times in which it was made. One-fiftieth of 360° is 7° 12′, which differs by only 3′ or 4′ from the true difference of latitude of the two places §; the meridional distance between the two parallels is about 787 kilometres, which taking a stade as 300 cubits (1 cubit = 0.527 metre), || corresponds to 4,971 stades, showing a very small difference from the assumed value; and the true circumference of the earth is very nearly 40,000 kilometres, or (taking the value just given for a stade) 253,000 stades, which is strikingly near to Eratosthenes' result.

The latitude of Syene appears to have been pretty correctly de-

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* According to GIRARD ("Description de l'Égypte," t. III,) Cleomedes states ("Meteora," lib. I, cap. 10 De terra magnitude) that Eratosthenes made the measurement at the *winter* solstice, and deduced the angle from the difference in length of the shadows.

† This value appears to have been subsequently altered to 252,000 stades, either for the sake of divisibility by 60, or in consequence of a small correction to the data. The last-named value is the one quoted by Strabo, Pliny, and other later writers.

‡ "STRABO, ("Geog." lib. II, c. I,) quoting Eratosthenes, gives the distance along the river as 5300 stades.

§ Our ignorance of the precise locality of Eratosthenes' stations renders any nearer estimation impossible.

|| This value of the stade is given by GIRARD, "Description de l'Égypte," Vol. III. He states that this was the only itinerary measure known to the Greeks. It does not appear, however, to be proven that a stade was exactly 300 cubits of the Elephantine nilometer, as is assumed. TOZER, "History of Ancient Geography," p. 172, takes 10 stades as equal to a geographical mile, which gives the value of a stade as nearly one-sixth greater; this would make Eratosthenes' value for the circumference about one-sixth too great.

termined by Hipparchus about 150 B.C., for he states * that there are 16,800 stades from the equator to Syene. As Hipparchus took Eratosthenes' determination of the earth's circumference (252,000 stades), and divided the circle into 360 degrees, it follows that his value of a degree was 700 stades. Thus the distance of 16,800 stades from the equator to Syene corresponds to a latitude for this place of 24°.

From the time of Eratosthenes onward till within two hundred years of our own times, geographical writers have described Aswan (Syene) as being situated on the tropic of Cancer, ignoring the fact that the position of the tropic is continually undergoing change. The condition that a place shall be on the tropic is that its latitude (which is of course practically constant) shall be equal to the obliquity of the ecliptic (which is constantly changing owing to planetary perturbation). For the epoch 1900 we have :—

Latitude of Syene (approximately).....	24° 5′ 5″
Obliquity of ecliptic, 1900	23° 27′ 8″
Difference	37′ 57″

The site of the ancient Syene is therefore at the present nearly 38′, or 71 kilometres, north of the tropic. The magnitude of this distance, combined with our knowledge of the present slow rate of decrease of obliquity (about 47″ or 1.4 kilometre per century) leads us to inquire whether Syene could possibly have been on the tropic in the days of the early geographers, or whether their observations were not erroneous. Two methods have been employed for tracing the variation in obliquity in past ages. One of these is by comparison of observations made at various epochs; the other is by computation from the known perturbating forces which affect the earth's motion.

The first, or observational method, possesses the disadvantage that the different values are not strictly comparable, owing to progressive improvement in the instruments employed. Sir Robert Ball † has collected the results of a large number of observations of the

* STRABO, "Geog.," lib. II, c.v.

† "Elements of Astronomy," p. 362.

obliquity of the ecliptic from very early times down to the present day. A few of the principal are :—

Year		Observer	Obliquity
B.C.	1100	Tcheou-Kong	23° 54′ 2″
	140	Hipparchus	23° 51′ 20″
A.D.	130	Ptolemy	23° 51′ 15″
	629	Litchou-Foung	23° 40′ 4″
	1525	Copernicus	23° 28′ 24″
	1800	Bessel	23° 27′ 55″
	1900	Newcomb	23° 27′ 8″

A mathematical investigation of the secular variation of the obliquity of the ecliptic has been carried out by Stockwell,* who shows that the limits of obliquity are 21° 58′ 35.6″, and 24° 35′ 57.5″. The following values of the obliquity at various epochs in the past are taken from Stockwell's tables :—

	Year	Obliquity
B.C.	6150	24° 15′ 24″·8
	5150	24° 12′ 40″·1
	4150	24° 8′ 43″·6
	3150	24° 3′ 41″·7
	2150	23° 57′ 42″·6
	1150	23° 50′ 55″·1
	150	23° 43′ 29″·6
A.D.	850	23° 35′ 37″·5
	1850	23° 27′ 31″·0

From these data it appears that the cataract was on the tropic about 3,500 B.C. In the time of the early geographers the tropic was very far south of Syene, though nearer to it than in our own day; in the days of Eratosthenes, for instance, the distance between Syene and the tropic was some 22′, or 40 kilometres. The mistake of placing Syene on the tropic arose entirely from the crude nature of the means employed for finding the sun's zenith-distance; and the error, at any rate in Eratosthenes' time, was quite an excusable one, having regard to the method of measurement. In the first place, since the sun's semi-diameter is 16′, no shadow would be cast by a

* "On the secular variations of the elements of the orbits of the eight principal planets."—Smithsonian Contributions to Knowledge, 1872, pp. 175, 196.

vertical gnomon 16′ north of the tropic; this leaves only 6′ unaccounted for, and it would be no easy matter, with the appliances then in use, to fix a gnomon truly plumb within this amount, while even if that were accomplished, the minute shadow which would be cast by a gnomon of moderate length would scarcely be observable. Besides the gnomon, it appears that certain wells at Syene were employed to observe the verticality of the sun at the summer solstice. These wells are mentioned by Strabo,* Pliny,† Ptolemy,‡ Heliodorus,§ and numerous other writers. Pliny expressly states that a well was sunk for the purpose of the experiment. The bottom of the wells being totally illuminated by the sun at the summer solstice, it was assumed that the sun was truly vertical; *i.e.*, that the wells were on the tropic. But here again the sun's semi-diameter needs to be considered, and the absolute verticality of the wells would be difficult to attain, while unless they were of great depth the shadows would be so small as to be easily overlooked. Take, for instance, a vertical well with smooth sides 20 metres deep; the shadow would have a width at the bottom in 230 B.C. of only about 3½ centimetres, which if the well were of large diameter might easily pass unnoticed.

But more serious than the original error was the non-recognition of the changes in the obliquity of the ecliptic, whereby the tropic is at present being removed about 1,400 metres per century southward. For it being constantly assumed that Syene was on the tropic, its latitude was continually altered to agree with the obliquity. Thus Ptolemy, having estimated the obliquity of the ecliptic about A.D. 130 as 23° 50′, gives this as the latitude of Syene.|| Had the observations with the gnomon or at the wells been repeated at this time, a shadow would almost certainly have been detected, and the variation of obliquity of the ecliptic perhaps discovered. As late as 1743 ¶ Aswan is referred to as "under the Tropic," and perhaps even in our own day the idea that Aswan is on the Tropic is not totally eliminated from the popular mind.

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* "Geog.," lib. XVII, c. I, 48.

† "Hist. Nat.," lib. II, c. 73.

‡ "Geog.," Translation by Magini Padovano, Venice, 1598 p. 151.

§ "Ethiopics," Books 8 and 9.

|| "Geog.," Book 4.

¶ POCOCKE, "A Description of the East." Chap. V.

The distance from Aswan to Philæ, which is actually 7 kilometres in a straight line, or about 9 kilometres by road or river, is given by Strabo * as 100 stades, which (taking 700 stades = 1°) corresponds to about 16 kilometres, and is thus twice too great.† Ptolemy, who as we have seen gave the latitude of Syene as 23° 50′, places Philæ in latitude 23° 30′, or 37 kilometres to the south; while in longitude he gives a difference between the two places of no less than 40′, *i.e.*, Philæ is placed about 68 kilometres west of the meridian of Syene, instead of on the same meridian as it actually is. In the Antonine Itinerary ‡ the distance from Syene to Philæ is given as M.P. III., or 4.55 kilometres, a value far too small; the III is perhaps a clerical error for VI., in which case the distance is pretty correct. The distance between the two places appears to have been first nearly correctly stated by an Arab writer, Ibn Selim el Aswani, who states that "the first city of Nubia is El Kasr §, five miles distant from Aswan; the last fortified place of the Muslims is the island of Belak,|| one mile distant from this city of the Nubians." ¶

THE LITERATURE OF THE FIRST CATARACT.

Consequent on the importance of the cataract in history and on its peculiar natural features, the number of literary references to it is extremely large. A few of these have been already cited, and most of the others of any importance will be mentioned further on in dealing with the points concerned. The following is a list, in chronological order, of the works which the author has noticed containing references to or treating of the Cataract, with brief notes on their contents; it is doubtless far from being complete, more especially in the domain of archæology, where the number of short memoirs is very great.

* "Geog.," lib. XVII, c. I, 50.

† PARTHEY, "De Philis Insula," p. 83, thinks the mistake arose by the frequent substitution in MS. of the letter P (100) for N (50). It is certainly remarkable that so accurate a writer as Strabo should overestimate the distance (which he himself traversed) so much.

‡ Quoted by Parthey, *op. cit.* p. 81.

§ The exact site of this city is uncertain, see p. 54.

|| Philae.

¶ Quoted by Makrizi about the beginning of the 15th century; see Appendix III to BURKHARDT'S "Travels in Nubia."

EARLY WRITERS

(From the sixth century B.C. to the fifteenth century A.D.)

Ezekiel, c. 29, 10, and c. 30, 6, refers to Syene as the border between Egypt and Ethiopia.

Herodotus, I., II., c. 28, 29 (English translation by *Rawlinson*, London, 1875, vol. ii.), gives an account of the Cataract, of which the only accurate portion refers to the method of navigation.

Cicero refers to the noise of the Cataract in the "Dream of Scipio," lib. II., c. 4. (English translation by *Edmonds*, London, 1884.)

Strabo, "Geography," lib. II., c. 5, and lib. XVII., c. 1 (English translation by *Hamilton* and *Falconer*, London, 1854–81), gives an account of Eratosthenes' measurement of the earth's magnitude, of Syene, of Elephantine and its nilometer, and of the Cataract and Philæ, with some historical details.

Diodorus the Sicilian, "Historical Library" (made English by *G. Booth*, Esq., London, 1721, p. 15) describes the Cataract.

Pomponius Mela, "De Situ Orbis," lib. I., c. 9 (French translation by *Nisard*, Paris, 1845) briefly describes the impetuosity of the Nile at the Cataract.

Lucan, "Pharsalia," lib. X. (English translation by *Riley*, London, 1853) makes mention of the Cataract.

Seneca, Nat. "Quæst.," 1, IV., c. 2, and "Epist.," 56, gives a striking description of the Cataract, and of the deafening effect of its noise.

Pliny, "Natural History," lib. II., c. 73, and lib. V., c. 9, 10 (English translation by *Bostock* and *Riley*, London, 1855), mentions the work of Eratosthenes, the wells of Syene, and the course of the Nile through the cataract district.

Martial, "Epigrams," book IX., c. 35 (English translation in *Bohn's Classical Library*, 1884), mentions "dusky Syene, watered by Egyptian floods."

Tacitus, "Annals," book II., mentions the archæological expedition of Germanicus to Elephantine and Syene, "the former frontier of the Roman empire."

Arrian, "History of Alexander's Expedition," to which is added Arrian's "Indian History" (English translation by *Rooke*, 1729). In vol. II., p. 252, mention is made of the well of Syene.

Ptolemy, "Geography" (Italian translation by *G. A. Magini Padovani*, Venice, 1598). No English translation of Ptolemy's work appears to exist; a bibliography of the "Geography" is given by *Winsor* in the *Harvard University Bulletin*, 1884. At pp. 148, 151 brief mention is made of Syene, its well, and the Cataracts, while the positions of Syene and Philæ are tabulated in book IV.

Aristides, "Orat. Ægypt.," XLVIII., gives a description at some length of the Cataract, down which Aristides ventured in a boat.

Philostratus in his "Life of Apollonius of Tyana" (English translation by *Berwick*, London, 1809, pp. 344–348), gives an account of the Cataract which is evidently coloured largely by the imagination; the rocks are described as eight stadia in height, tenanted by demons.

Solinus, "Polyhistor," c. 35, copies Pliny's description of the district almost word for word.

Marcellinus, "Roman History" (English translation by *Yonge*, 1852), book XXII., c. XV., 9, briefly mentions the Cataracts and their deafening action on the Ati; apparently an abridgment of the accounts of Pliny and Seneca.

Dionysius Periegetes, in his "Periegesis," a Greek poem describing the world, makes mention of the Cataract.

Eustathius, commenting on the "Periegesis" in the latter half of the twelfth century, refers to the description of the Cataract (Geog. veter. script. Græc. minor, t. IV., Oxon., 1697, verses 220, 244, 251).

De Joinville, in his "History of Saint Louis, King of France" (English translation by *Hutton*, London, 1868), recounts a tale told by emissaries of the Sultan of Babylon, who asserted that at the Cataract the river fell over huge precipitous rocks, tenanted by lions, elephants, and other wild beasts.

Nicephorus Callistus, "Eccles. Hist.," Paris, 1630, t. I., l. IX., p. 724, mentions that the Nile at its entry into Egypt precipitates itself from high rocks with a loud noise.

ARABIC WRITERS.

Ibn Selim el Aswani, "Notices on Nubia, Mokra, Aloa, Bedja, and the Nile," quoted by Makrizi in "El Khitat" (English translation by *Burckhardt* in the Appendix III. to his "Travels in Nubia." French translation in Quatremère's "Mémoires géographiques et historiques sur l'Égypte," Paris, 1811, t. II.), contains interesting historical and topographical references to the cataract district.

Makrizi, "History and Description of Egypt (el Khitat)," besides embodying the writings of Ibn Selim, himself describes Aswan and refers to its history. (English and French translations mentioned above).

Leo Africanus, "History and Description of Africa" (done into English in 1600 by Pory, and republished in 1896 by the Hakluyt Society), vol. 3, p. 903, gives by a curious error Esna as the site of Syene, and describes Aswan, its ruins, people, and Nubian trade.

REFERENCES IN EARLY GEOGRAPHICAL TREATISES, AND WORKS BY MODERN TRAVELLERS, ARCHÆOLOGISTS, ARTISTS, AND MEN OF SCIENCE.

Sandys, "Travailes. Containing . . . a Description . . . of Ægypt; the Antiquity, Hieroglyphicks, etc." The fifth edition, London, 1652, pp. 73, 86. Mainly a repetition of the descriptions given by Herodotus, Lucan, and Seneca.

Heylyn, "Mikrokosmos, a Little Description of the Great World," 5th edition, Oxford, 1631, pp. 7, 736. Refers to Syene as the centre of the third "clime," and briefly describes the Cataract from the accounts of the classical writers. The same author, in his "Cosmography," London, 1677, book IV., pt. I., p. 12, shortly mentions "Syene, now Asina," as situated on the Tropic, and memorable for a deep well digged by some astronomers.

Lenz, "De hominibus ad catadupas Nili obsurdescentibus," Wittenberg, 1699. In this opuscle are collected all the classical passages about the Cataracts and their roar, which was, it is said, so great that the inhabitants of the neighbourhood were deafened by it.

Baudrand, "Dictionnaire Géographique et Historique," Paris, 1705. Mentions the site of Syene as uncertain, being placed by some at Esna, by others at Aswan. Further on Elephantine is spoken of as *vis-a-vis* to Esna. This confusion of Esna and Aswan is fairly common in works of the period.

Sicard, "Mémoires des Missions du Levant," t. VII., p. 121, contains an account of the cataract.

Paul Lucas, in his "Voyage au Levant," La Haye, 1705, t. I., pp. 95, 96, gives a curious account of the Cataract, from which it would appear that the fall was formerly much greater than at present. But a story he tells further on, about men with only one leg being able to run very fast, tends to make one receive his statements with caution.

Pococke, "A Description of the East and some other Countries," London, 1743. Chap. V. of book II. is entitled "Of Assuan, Syene under the Tropic, Elephantine, the Quarries of Granite, the Cataracts, Phylæ, and the Borders of Ethiopia."

Norden, "Voyage d'Égypte et de Nubie," Paris, 1795–98, t. III., p. 27, contains a map of the course of the Nile from Philæ to Syene, but has only a brief reference to the Cataracts.

The French Expedition. "Description de l'Égypte, ou Recueil des Observations et des Recherches qui ont été faites en Égypte pendant l'Expédition de l'Armée Française." Paris, 1809. Of this magnificent work, in which some of the most talented scientists and artists of France were employed, two editions have been published. In the first, the text is in folio volumes; while in the

second (1819) a handier octavo size has been adopted. Both editions were accompanied by very large atlases of plates. The principal chapters relating to the Cataract District are in vol. I. They are : " Description de l'Ile de Philæ," by LANCRET ; " Syene et ses Cataractes," by JOMARD ; " Ile d'Éléphantine," by JOMARD ; and " Description des Carrières," by DE ROZIÈRE. Vol. III. contains a " Mémoire sur le Nilomètre de l'Ile d'Éléphantine et les Mesures Égyptiennes," by GIRARD, while in Vol. IV. there is an " Exposé des Resultats des Observations Astronomiques " (including those at Syene and Philæ) by NOUET. Vol. I. of the " Atlas " has a large number of plates illustrative of the Cataract district, mostly of a high degree of excellence. In some cases these pictorial records are specially valuable as illustrating structures which have since disappeared.

BRUCE, " Travels to Discover the Source of the Nile," 2nd edition, Edinburgh, 1805, vol. II., p. 56, describes Syene, with a determination of its geographical position, and the Cataract.

DENON, " Voyage dans la Basse et la Haute Égypte," London, 1809. Briefly describes the Cataract district, with a number of illustrations. The " well " of Syene is thought by Denon to be the nilometer of Elephantine.

QUATREMÈRE, " Mémoires géographiques et Historiques sur l'Égypte," Paris, 1811, is a collection from Coptic and Arabic MSS. in the Imperial Library. In vol. II. are given notes on the history and topography of Aswan, from the writings of Makrizi, Masudi, and others.

BURCKHARDT, " Travels in Nubia," London, 1819, gives a short description of the Aswan district, and in a valuable appendix gives translations of the works of some Arabic writers relating to Nubia ; Burckhardt thus performed a similar service for English readers to that which Quatremère had already done for French.

PARTHEY, " De Philis Insula," Berlin, 1830. A short Latin commentary on the monuments, with references to classical writers.

ROBERTS, " Egypt and Nubia, from drawings made on the spot," 1846. In the first two large folio volumes of this work are some beautifully executed drawings of the Cataract district, chiefly of the temples of Philæ.

LETRONNE, " Recueil des Inscriptions grecques et latines de l'Égypte," Paris, 1842–48. In vol. II. of this work the history of Philæ under Greek and Roman rule is deduced from the inscriptions on the monuments.

LEPSIUS, " Ueber die in Philæ aufgefundene Republikation des Dekrets von Rosette," Leipzig, 1847. The same author gives illustrations of the antiquities of the Cataract in parts I., III., IV., and VI. of his large work " Denkmäler aus Ægypten und Æthiopien," Pisa, 1849–59. These plates are unaccompanied by text, but a short account of his expedition is given in his " Letters from Egypt," London, 1853.

NEWBOLD, " On the Geology of Egypt," Quart. Jour. Geol. Soc., London, 1848.

Delesse, "On the Rose-coloured Syenite of Egypt," Quart. Jour. Geol. Soc., London, 1851, pp. 9–13.

Unger, "On the Fossil Wood of Egypt," Quart. Jour. Geol. Soc., London, 1859, part II., p. 13, mentions fossil wood from Aswan.

Hawkshaw, "A Geological Description of the First Cataract," Quarterly Journal Geol. Soc., London, 1867, pp. 115–119. A brief but accurate account, with a map.

Fraser and Wood, "Sketch Map of the Environs of Aswan," London, War Office, 1884.

Dawson, "Geology of Egypt," Geol. Mag., 1884, pp. 289–292, 385–392, 439–442, refers at some length to the rocks of the Aswan district, correlating them with North-American deposits.

Revillout, "Mémoire sur les Blemmyes," Paris, 1874. A consideration of the history of the Blemmyes about the period of 552 A.D., in the light of a Coptic inscription found at Dendur.

Bonney, "Note on the Microscopic Structure of some Rocks from the Neighbourhood of Aswan," Geol. Mag., 1886, pp. 103–107, describes the rocks collected by Dawson.

Brugsch, "Die biblischen sieben Jahre der Hungersnoth," Leipzig, 1891. A discussion of the famine-stela found on Sehel Island by Willbour.

Raisin (Miss), "Rock Specimens from Upper Egypt," Geol. Mag., 1893, pp. 436–440. Contains a description of some rocks from the First Cataract.

De Morgan (and others), "Catalogue des Monuments et Inscriptions de l'Égypte Antique, Première Série, t. I. De la Frontière de Nubie à Kom Ombos." Vienna, 1894. Contains an enumeration of most of the antiquities of the Cataract district, except Philæ. The hieroglyphic inscriptions which form the major part of the illustrations in the work are not translated.

Canney, "The Meteorology of Egypt and its Influence on Disease," London, 1897. Contains some references to the climate of Aswan.

Lyons, "A Report on the Island and Temples of Philæ," Cairo, 1897. Contains collotype prints from photographs of most of the ruins on the island, with plans and some structural details.

Maspero, "The Dawn of Civilisation," 4th edition, London, 1901; "The Struggle of the Nations," London, 1896; and "The Passing of the Empires," London, 1900 (translated from the French by McClure). In these three volumes will be found the history of Egypt from the earliest times to the end of the Pharaonic period, with copious references to original sources.

PETRIE, "History of Egypt." Vol. I. "From the Earliest Times to the XIVth Dynasty." Vol. II. "The XVIIth and XVIIIth Dynasties." London, 1899.

MAHAFFY, "The Empire of the Ptolemies," London, 1895.
„ "The Ptolemaic Dynasty," London, 1899.

MILNE, "History of Egypt under Roman Rule," London, 1898.

LANE POOLE, "History of Egypt in the Middle Ages," London, 1901. This and the two preceding works form a continuation of Prof. Petrie's two volumes. References to the history and antiquities of the Cataract district will be found scattered through all the volumes. Like that of Prof. Maspero, this series of histories is rendered of great value by the copious citation of original papers.

BUDGE, "A History of Egypt from the End of the Neolithic Period to the Death of Cleopatra VII., B.C. 30," 8 vols., London, 1902.

The guide-books of Baedeker, Murray, and Hachette are too well known to require more than mention. As they have mostly been written with the collaboration of learned Egyptologists, their information is generally quite trustworthy as far as it goes, and the short accounts given of the Cataract district are admirable as brief general descriptions. *

OUTLINE OF THE WORK OF THE GEOLOGICAL SURVEY AT THE CATARACT.

At the time of the commencement of the new reservoir works at Aswan in 1898, only so much of the cataract area as was necessary for the engineering work had been surveyed in detail, and no systematic geological examination of the district had been made, though its general nature was known from the papers published by Hawkshaw and others. In the spring of 1899, some interesting rock exposures having been laid bare during the excavations for the foundations of the reservoir dam, a detailed geological survey of the entire area was decided upon.

The first necessity was to produce an accurate topographical basis for the geological mapping. So complicated an area could of course only be mapped with a network of small triangles as a foundation.

* Since this memoir was written, a paper has been published by M. R. FOURTAU (Bull. Soc. Khédiviale de Géographie, VI[e] Série, N° 7, pp. 325-363), in which the origin of the Aswan cataract is ascribed to complex faulting.

But with the short time available, it was impossible to delay the detail work until all the triangles had been chosen, measured, and computed; as soon as a few triangles had been determined, these had to be forthwith plotted on plane-table sheets,* which were filled in with topographical detail for this portion whilst the triangulation was continued. An excellent base was found in the line of the new reservoir dam, which had been set out by Mr. Bakewell, and by repeated measurement found by him to have a length of 1966.43 metres.

There being no lack of suitable observation points, a triangulation net was rapidly thrown over the area, the lengths of the sides varying from less than one to over six kilometres. The necessary time could not be spared for a thorough preliminary reconnaissance, so that the points could not be chosen with that regard to equilateral shape of figure which is desirable in important triangulations; but the area was well covered with, on the whole, fairly well-shaped triangles. The angles were measured with a five-inch vernier theodolite reading to twenty seconds; but as the stations were not very precisely defined, being usually the centres of tombs or other structures, no very great precision of angular measurement was attempted, a closure error of less than two minutes in a triangle being disregarded; with the short lines employed, the length error caused by this closure error after distribution cannot have exceeded a fraction of a metre, an amount insensible on the scale employed ($\frac{1}{10000}$). A tacheometrically measured base of verification in the north part of the area proved the accuracy of the work within the limits aimed at, viz., 1 metre per kilometre of uncertainty. The entire triangulation, including the computation (which was done in camp at night) and plotting of the points on the plane-table sheets, occupied some ten days; but, as already mentioned, the filling in of detail by plane-table was going on simultaneously, and moreover the triangulation was done at intervals as the work proceeded, keeping well in advance of the sketching.

The heights of the triangulation-points above sea-level were determined by angular elevations, with a bench mark at 109 metres above sea-level as starting point. The instrument employed was an eight-inch

* The plane-table sheets each measured 59 × 42 cm., and thus with the scale adopted ($\frac{1}{10000}$) correspond to an area of 24·7 sq. km.

vernier theodolite reading to ten seconds. Refraction (k. $=0.18$) was duly allowed for, and instrumental errors were eliminated by change of face; it is believed the heights are correct to one-tenth of a metre.

In the filling-in of topographical detail by the plane-table method, the hills were indicated by form lines approximating to contours at six-metre intervals, as estimated by eye and controlled by the measured heights of the trigonometrical stations. Distances were measured by a five-inch tacheometer, this instrument being constantly set up side by side with, and as close as possible to, the plane-table. By this method, bearing in mind the proximity of the triangulation points, it was difficult to make an error of distance exceeding one or two metres. The topographical sketching was almost entirely done by Mr. J. T. Dillon and Mr. H. G. Skill.* The fairly large scale ($\frac{1}{10000}$) of the field map rendered it possible to insert a considerable amount of detail in the sketching, and every care was taken to ensure as much as possible being shown. †

In the delineation of the water-line, the alteration due to the rise and fall of the river, as well as to the variation of the distribution of water in the cataract channels in consequence of the temporary dams constructed by the engineers, was the source of a little difficulty; but this was obviated as far as possible by getting the water-line drawn in as rapidly as might be consistent with accuracy. The map of a district like the cataract can of course only be correct as regards the water-surface at two particular epochs of each year, owing to the rise and fall of the river covering and uncovering the low-lying rocks and mud-banks. The mean level of the water-surface at the Aswan nilometer during the survey was 86.75 metres ‡ above sea-level, which is 2.25 metres below the mean level of the river; so that more than the average area of ground was laid dry during the survey. The map will be approximately correct in an average year about the middle of February, and again about the middle of July; between February and July more, and between July and February less, of the islands and mud-banks will be exposed.

* Mr. Skill took Mr. Dillon's place in the spring of 1900.

† The field map has been reproduced on the original scale, and is published by the Survey Department in 6 sheets. The topographical map which forms the frontispiece to this memoir is a reduction from the field-map, much detail being in consequence unavoidably omitted.

‡ See Plate 7, p. 31 of Willcocks' "Egyptian Irrigation," 2nd Edition; the mean maximum for the ten years 1874-1883 is 92·8 metres, and the mean minimum for the same period 85·2 metres

For the orientation of the map, the azimuths of a number of the principal triangulation lines were determined from star observations. The absolute geographical position of one point, and thus of the whole, was determined, the latitude by a series of altitudes of north and south stars, the longitude by theodolite observations for local time and telegraphic chronometer comparisons with Cairo. The point selected was the Roman ruin commonly known as "Cleopatra's Bath," which abuts on the river near the centre of the town, and the position found was lat. 24° 5′ 15″ N., long. 32° 53′ 38″ E., of Greenwich. Subsequent triangulation operations up the valley from Cairo have, however, given the position with greater precision as lat. 24° 5′ 18.5″ N., long. 32° 53′ 26.7″ E. of Greenwich, and this latter value is the one now adopted.

The magnetic variation was observed, using a theodolite compass, to be fairly constant over the area; its mean value (A.D. 1907) is 3.1° W. Small variations, generally less than 1° in amount, were noticed near basalt dykes on the west bank. The secular change of declination is now probably about 4′ or 5′ per year (diminishing). * The plane-table surveying was kept absolutely independent of the compass.

For the insertion of the geological boundaries two methods were used. In the earlier one, employed on the south part of the area, the author furnished himself with a sketch copy of the topographical map as far as it had been completed, and then went over the ground, sketch and compass in hand, making notes which were afterwards transferred to the actual map in camp. This method, though the only one possible so long as only one field-sheet was in progress, left something to be desired in point of directness, and in the major portion of the work matters were so arranged that two plane-tables were kept at work on different portions at the same time, one by the author and the other by his topographical assistant, the two changing hands as often as found desirable. In this way the geological matter was drawn directly on the field-sheets with the aid of the

* A comparison of the declination observed by Cailliaud in 1819 with that found by d'Abadie in 1885 gives the change as 6′.1 per year. The difference between d'Abbadie's observation and that of Capt. Lyons in 1895 indicates the lower value of 4′.7. The rate of change is thus probably becoming slower. See LYONS, Proc. R.S. Vol. 71, p. 17.

ordinary plane-table appliances, and besides the greater accuracy in representation of geological boundaries thus rendered possible, this second method possessed the advantage that the topographical sketch was twice gone over in the field, so that any small error in drawing was at once detected and adjusted on the spot at the same time that the geological notes were entered.

Many of the smaller cataract islands were found to be inaccessible to boats at the time of survey; these were mapped with the aid of Shellali swimmers, who shot the rapids on their wood logs and either held the telemetric staff or broke off pieces of the rocks for examination as required.

The sections which accompany the report were levelled in the ordinary tacheometric manner, and checked by trigonometrical observations at their terminal points. In no case did the error found by these observations exceed one metre, and this value was only approached on long lines, so that the sections are accurate well within their scale-limits, and possess a precision beyond what is required for their destined geological purpose. Very special attention was given to the sections exposed in the excavations for the dam-foundation and navigation-channel; these exposures exhibited very clearly that tremendous crushing and faulting of the igneous rocks which is one of the main characteristics of the district. The whole line of section in these works could not of course be examined at any one date, as the dam-trench was built in, and the navigation-channel in places pitched, as the work proceeded; but a large portion was examined at the time of the survey, and the remainder was added on subsequent short visits made for the purpose.

The time occupied in the field work was in all a little over four months (March 1st to April 7th, 1899, and Nov., 3rd, 1899 to Jan., 7th, 1900). The field maps and sections were all finished up and coloured complete while still in the field. The staff comprised the author and his assistant, with generally six native porters; a boat with three men, a camel (for water transport), and a couple of donkeys were kept in almost constant employment. The rate of progress works out to about 0.6 square kilometre per day, inclusive of triangulation, section-levelling, and geological examination; the cost of field work inclusive of salaries of the author and his assistants, but exclusive of any allowance for wear and tear of instruments, was approximately LE.7 per square kilometre.

In the course of the close examination of the district which the survey demanded, it is believed that nearly all the archæological remains (with the exception of the numerous and closely aggregated inscriptions on the road between Aswan and Philæ, and on the rocks of the islands, which have been already catalogued by De Morgan), were precisely located, and thus the map will, it is hoped, render service to archæologists.

CHAPTER II.

TOPOGRAPHY.

GENERAL OUTLINE OF THE TOPOGRAPHY OF THE CATARACT.

The most striking feature of the topography of the cataract district is the complexity of detail which it presents. To this complexity of detail is due the entirely different character of the cataract scenery as compared with that of other parts of Egypt. Elsewhere in the Nile Valley we are accustomed to broad plateaux and long, wide wadis, to a peacefully flowing river bordered by green corn-fields. But at the Cataract the plateaux give place to rugged hill-masses cut up by narrow valleys and gorges, while the river pursues a troubled and branching course amongst a multitude of rocky islets, and the fertile plains are represented only by small patches of alluvium dotted about amongst the rocks. This difference in topographical character is principally determined by a difference of geological structure, the sedimentary rocks of the main portion of the Nile Valley here giving place to eruptive masses.

The town of Aswan occupies a comparatively flat tract of land on the east bank of the river below the Cataract. The remaining villages of the district are scattered about the banks and larger islands in localities where the general stony nature of the ground is relieved by a few acres of alluvium. The only island possessing any large cultivated area is Elephantine; the remaining islands are rocky and hilly, frequently rising to heights comparable with those of the adjacent desert hills.

The Nile dam crosses the river about 6 kilometres south of Aswan, passing over several islands in its course. In the winter season the river is held up to a height sufficient to cover the smaller islands up-stream of the dam, and the larger ones are also partly submerged, so that the view from the dam to the south at such times is more like a lake than a river scene.

The west bank is the part of the district which most nearly approaches the rest of the Nile Valley in structure and appearance, the eruptive rocks being there mostly covered by sedimentary sandstone. The slopes are, however, sandy and inhospitable.

The east bank is much more varied in outline than the west, consisting chiefly of bare rugged masses of granitic rocks, though there are some extensive flat-topped hills covered with sandstone. The railway-line from Aswan to Shellal runs through a wide valley among the hills at some distance east of the river; the floor of this valley is of sand and gravel, showing it to be an old river-bed. It is, in fact, a former channel of the Nile which is now left dry.

It will be convenient to consider the detailed topography of the district in the following order:—

(1) The Nile and the Cataract.

(2) Aswan and its environs.

(3) The country between Aswan and Philæ (east bank).

(4) The Cataract islands between Elephantine and the dam.

(5) The west bank between the Monastery of St. Simeon and the dam.

(6) The Nile reservoir.

(7) The islands south of the dam.

(8) The east river-bank south of the dam.

(9) The west river-bank south of the dam.

I.—The Nile and the Cataract.

The Nile may be considered as entering the Cataract district at the southern extremity of El Hesa, the largest of the group of Cataract islands. At this point, the river, which has a width of about half a kilometre, divides into two branches, of which the eastern one is by far the wider and takes practically the whole discharge except in flood or with a full reservoir; the western channel is narrow and much blocked by islands and rocky protuberances from its banks, though enough of these have been recently removed by blasting to give a sufficient passage to boats. The river again branches about two kilometres further on, flowing round the islands of Biga and Philæ, and sending a narrow branch down the rocky channel separating El Hesa and Awad islands. The two main arms of the river reunite near

Shash island, and then the waters take a sharp turn to the west. It is at this place that the first increase of velocity in the stream, due to its approach to the Cataract, is noticed. A considerable discharge formerly took place into the west channel here, by means of an artificial cut made by Mohammed Ali and recently filled up; owing to the throttling of the west channel already referred to, the water flowing through it was retained at a lower level than that of the main stream, so that an even greater rush of water took place here than at the natural cataracts, and the place was in consequence frequently called by the Arabs "Bab el Kebir," a name properly applied to the greatest of the natural rapids.

The reservoir dam crosses five principal natural channels, called respectively the West Channel, the Central Channel, the Bab el Kebir, the Bab el Harun, and the Bab el Soghair. Of these, the last four form the main natural cataracts. The dam is, of course, built near the highest parts of these channels, the depths of which near the dam at low Nile are 9, 2, 8, 2, and 6 metres. At high Nile the river rises above the levels of the islands separating the different channels, and forms a broad stretch of troubled waters extending across from Thirmosia Island to the west bank. It is only at low Nile that the splitting up into separate channels takes place, and then the rush of water through them is so great as to carry down-stream blocks weighing several tons.* The west channel has a less strong current, the head here being, as already mentioned, lessened owing to the throttling of its approaches.

The natural distribution of the water is not affected to any considerable extent by the dam during the time of high Nile, when all sluices are open. At low Nile, when the reservoir is full, the distribution among the various channels is somewhat affected, the amount depending on which groups of sluices are open at any particular time.

Beyond the dam the river splits up still further, passing in foaming rapids round a large number of small rocky islands, many of which are completely submerged when the stream is in flood; the main stream, which south of the dam occupies the eastern channel, now passes to the west side, and fairly smooth water exists along the west channel for about a kilometre beyond the north end of the new navi-

* Fitzmaurice. "On the Nile Reservoir," Proc. Inst. C. E., CLII., pp. 93, 94.

gation canal. As Sehel island is approached, however, a formidable rush of water occurs at the Bab Hemedai, where the channel is shallow and throttled by islets.* From the Bab Hemedai, which is the last of the cataracts, the main flow continues to be carried by the west branch of the river till Sehel island is passed, when the eastern and western branches take on approximately equal shares of the discharge. A small discharge, however, goes on through rocky channels round the south and east of Sehel.

In the neighbourhood of Aswan and Elephantine a considerable natural change seems to have been taking place within recent times in the distribution of the water. Thus the eastern channel becomes at times so silted up that at low Nile it is possible to wade across to Elephantine, while the western channel is quite safe for steamers. Extensive sandbanks form on the east bank close to Aswan, and it has been recently found necessary to dredge the river in order to permit the ascent of even small steamers by this channel. A corresponding erosion of the west bank is doubtless going on.

The total drop in the river level being only 5 metres between Aswan and Philæ, it will be seen that the fall at the cataracts is only a small one at the present day, not exceeding about 3 metres in any one "bab." The numerous obstructions cause an amount of noise and foaming which is usually associated with a larger fall, and the contrast with the placidity of the river throughout the remainder of its long corresponding course to the sea further heightens the effect.

The accounts of classical writers,† some of whom assert that the noise of the cataract was so great as completely to deafen the people residing near it, and all of whom describe it as a great waterfall, were doubtless exaggerations. Nevertheless it is probable that the fall may have been greater in former times, for the river is perpetually grinding out its bed into a more uniform channel, and the continual action of rapids which can sweep along stones weighing several tons cannot but produce significant change in the course of centuries. This question will be further considered in dealing with the geology of the cataract.

Navigation of the Cataract was, until recently always a matter of

* Navigation of this part of the river has been facilitated by the construction of a lock.

† See the list of literary references on pp. 15-20.

great difficulty,* and impossible except at or near the period of high Nile. The construction of a canal at the west side of the dam, with a series of four locks, and of an additional lock at the Bab Hemedai, has done away with this difficulty, and all kinds of boats can now pass easily at any time of the year.

II.—Aswan and its Environs.

Aswan † is the chief town and seat of government of the Nubian province (Mudiria), which extends from near Esna to the southern frontier of Egypt (lat. 22°). The town is connected directly by railway with Cairo, from which it is 882 kilometres distant; but communication with the south is at present possible only by river steamer, the connecting link of railway between Aswan and Wadi Halfa not yet having been projected.

The population of Aswan (exclusive of Elephantine and other neighbouring villages) in 1897 was 13,101, of whom 74 were foreigners, chiefly Greeks and English. The number of houses at the same time was returned as 3,442, and the religious classification of the people gave 12,214 Muslims, 871 Christians and 15 Jews. About 95 per cent. of the population are illiterate.‡

The town, which covers an area of rather more than half a square kilometre, abuts closely on the river, and at its southern end occupies the flank of a low granite hill. The frontage to the river is one of the finest in Egypt, a stone-faced embankment forming a promenade from end to end of the town. It is on this promenade that most of the Government offices and other more important buildings have their frontages. Of the internal streets, the most important is the bazaar, a narrow covered-in way running nearly parallel with the river and containing most of the curiosity shops frequented by tourists, as well as many of the native stores.

Aswan possesses few buildings of any magnitude other than the

* Herodotus' description, book ii, c. 28, of the method of hauling boats up the cataract over two thousand years ago, was almost a true description of the practice up to the end of the last century.

† For the position of Aswan, see p. 8.

‡ "Recensement Général de l'Égypte," 1st June 1897.

recently erected hotels; the most important are the mudiria or governorate, the police station, and the schools, all of which face the river. The principal mosque is a little way back, near the police offices and at the entrance to the bazaars. An English church has been built on a slight eminence at the south end of the town, near the Cataract Hotel, and an Austrian Catholic church faces the river at the north end of the promenade. The railway station is close to the Nile at the south end of the town.

Steamers land their passengers near the centre of the town-front at high Nile, but in low states of the river when there is too little waterway east of Elephantine for this to be done, landing is effected further north. Ferry-boats to Elephantine and the west bank ply from landing-places close to the police-station.

Though the chief town of the southern province of Egypt in very ancient times was on the island of Elephantine, it is most probable that another town existed on or near the site of the present Aswan as early as the time of the Fourth dynasty. For at that time began the great building operations which have left us the Pyramids; and special portions of these monuments, such as the lining of the king's chamber in the pyramid of Kheops, the royal sarcophagi, etc., are constructed with great skill of Aswan granite,* showing that quarrying operations on a considerable scale were then undertaken; and a large quarrying industry implies a settlement of some kind in the immediate neighbourhood. This inference is confirmed by the mention of Aswan under the name Eo Sunnu on monuments of the Fourth and Fifth dynasties.† It is, indeed, almost certain that the site of Aswan has been continuously occupied by a town for the last 5,000 years, though few of the buildings now standing date back more than a small fraction of this period. By the Greeks the town was known as Syene, and the prophet Ezekiel ‡ (about 450 B.C.) refers to it as the frontier between Egypt and Ethiopia. The importance of Syene in ancient geography will be referred to further on. Under the Roman Empire Syene was the scene of many conflicts with the Ethi-

* There is no difficulty in distinguishing the red granite of Aswan from that of Hammamat (in the Eastern Desert), which was probably worked at an equally early date. The Aswan rock is of a coarser grain and darker colour than the other.

† BRUGSCH, "Dict. Geog.," pp. 664 *et seq*.

‡ Chap. 29, v. 10; chap. 30, v. 6.

opians, and was garrisoned by Roman soldiers.* After the Roman forces were withdrawn and Aswan had fallen into the hands of the Mohammedan conquerors, it was again the scene of bloody conflicts with the Nubians, who at this time were Christians. Thus we read † that in 956 (A. H. 344) the king of Nubia attacked Aswan and killed many Muslims; in the following year the Egyptian army marched against him, and he was beheaded, with many prisoners. In the twelfth and thirteenth centuries Aswan appears to have been a town of great importance. For in the year 1188, says Kadi el Fadl, the income of the port of Aswan was 25,000 dinars, while Jafar el Edfui states that there were at Aswan 80 officers of the tribunal of justice, and that the town in one year produced 30,000 ardebs of dates; he also adds that he met with a book dated A.H. 620 (about A.D. 1223) which mentioned the names of forty authors of Aswan.‡ The numerous ruins of elegant Arab tombs about Aswan attest the importance of the place about this time. In 1403 it is related that 21,000 persons died of plague at Aswan, and the town remained for a long time deserted. In 1412, in consequence of a feud between the Howara Arabs and the Beni Kenz, the former tribe destroyed the walls of the city, killing many men and reducing the women and children to slavery. Under the Sultan Selim, who took possession of Egypt in 1517, the castle of Aswan is said to have been rebuilt by Bosnian soldiers.

Though still probably much smaller than it was during the Middle Ages, Aswan has of late increased considerably in importance, from a variety of reasons. It has only recently been connected by railway with Cairo. The opening-up of the Sudan has increased the through trade, all goods passing south having to be transferred to boats at or near Aswan for the connection to Halfa, where the railway can be resumed. The building of the reservoir, and the circumstance that Aswan has lately come into some prominence as a health resort, have also conditioned its extension.

The climate of Aswan is a very pleasant one from November to March, being dry and sunny without excessive heat. During the

* Milites Miliarenses, and Cohors V. Syenensium, stationed at Syene about A.D. 425. (See MILNE, "History of Egypt under Roman Rule," Appendix I.)

† Ibn Selim el Aswani, quoted by MAKRIZI, "El Khitat," (15th century; extracts are given in English in Appendix III, BURCKHARDT's "Travels in Nubia," London 1819).

‡ Translation in Burckhardt, *op. cit.*

rest of the year the temperature is generally too high for comfort. Rain occurs but seldom; but one or two sharp downfalls may be experienced early in the year.*

The natives, who are considerably darker in colour than the ordinary Egyptians, are of fair intelligence and physique. Though they can speak and understand Arabic, a large proportion of the population, especially the people of the islands, speak among themselves a Nubian dialect. A large part of the industry of Aswan consists of river trade, and the Nile bank north of the town generally presents a busy scene. There is not much cultivated land in the vicinity, most of the produce consumed coming from further north.

The suburb of GATANIA consists chiefly of the dwellings of poor Sudanese. The villages of HADADIN BAHARI and RAML EL KHADIB, to the north of Aswan, lie on a flat tract with numerous palms and cultivated tracts, and possess no features of importance. An encampment of Bisharin Arabs lies close to the east of Aswan; the Bisharin employ themselves chiefly with camel-rearing, and they travel far into the desert to find grazing for their animals. But a section of them are engaged in making the leather necklaces and other curios which are sold in the bazaars. The fine physique of the younger Bisharin will not fail to strike every visitor to the place.

ELEPHANTINE, or the Geziret Aswan, is an island lying near the centre of the river facing Aswan town. It is about 1½ kilometres in length, and 400 metres in breadth at its widest part. It has two small villages, called respectively El Ramla and El Kom, with a large cultivated area between them.

Elephantine was an important place under the old empire. Manetho informs us that the Fifth dynasty consisted of Elephantine kings,† and there are inscriptions of many of the kings of succeeding dynasties still visible on the rocks. In Roman times a garrison was maintained at Elephantine.‡ The importance of the place was still considerable in the Middle Ages, for we read that in the time of the Sultan Saladin

* For a discussion of the climate of Aswan from a medical point of view, see DR. LEIGH CANNEY "The Winter Meteorology of Egypt and its Influence on Disease," London 1887.

† The small size of Elephantine Island has led to speculations as to the accuracy of Manetho's statement; v. JOMARD, "Description de l'Égypte," vol. 1; PETRIE, "History of Egypt," vol. 1, p. 70; LEPSIUS, "Königsbuch," 20, 21.

‡ Cohors I. Felix Theodosiana, stationed at Elephantine about A.D. 425. v. MILNE, "History of Egypt under Roman Rule," Appendix I.

(A.D. 1171) the king of Nubia fell on Elephantine with 10,000 men and took all the Muslim inhabitants of the island prisoners.*

The principal ancient structure now existing on Elephantine is the Nilometer,† on which readings of the height of the Nile were taken in Roman times, if not earlier. The present scales date only from 1869, when, as is recorded by an inscription in French and Arabic, the astronomer Mahmud Bey was charged with the work by the Khedive Ismail; but inscriptions on the walls of the staircase still record the height of the river at different dates during the Roman period, and the old scale of cubits may still be seen.

The other ruins on Elephantine are fragmentary. A granite portal bearing an inscription of Alexander II. is all that remains of what so recently as the beginning of last century was a fine temple of Amenhotep III.; this was of a form totally different from the usual one of Egyptian temples. A smaller temple of Tothmes III. probably also existed a little further north, but of this even scantier remains are now left. The stones of the quay-wall at the south-east of the island are derived from temples of Tothmes III. and Rameses II.; they contain some well-preserved inscriptions, referring principally to the calendar.‡ The granite boulders near the site of the ancient town bear inscriptions of very early date, some of them going back to the fourth dynasty. The mounds of rubbish have yielded various fragments of papyri, including a portion of the Iliad, as well as small bronzes, coins, and fragments of inscribed pottery.

The small island of ATRUN, situated west of Elephantine, is cultivated as a garden.

The immediate ENVIRONS OF ASWAN present many points of interest to the visitor. Close to the south end of the town, almost completely buried in the ground is a small TEMPLE erected by Ptolemy IV., which was, however, never finished. Another temple of the same epoch formerly existed a little further south; but of this only *débris* remains.§

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* MAKRIZI, quoted by BURCKHARDT, *op. cit.*

† An interesting account of the Nilometer of Elephantine, with a discussion on the origin of the cubit adopted in its measurements, is given by GIRARD in the third volume of the "Description de l'Égypte," and views of it are given on Plate 33 of the Atlas of Antiquities accompanying that work. A later account, with an illustration, is given in DE MORGAN'S "Catalogue," p. 123; from this it is observable that much of the staircase was destroyed between 1799 and 1894.

‡ DE MORGAN, "Catalogue," pp. 103-125.

§ Descriptions of these temples, with illustrations, are to be found in DE MORGAN'S "Catalogue," pp. 48–57. See also Plates 22–26 of MARIETTE'S "Monuments divers recueillis en Égypte

The Roman Ruin which stands on a slighty projecting point of the river bank close to the Mudiria, and which is commonly (and of course erroneously) known as "Cleopatra's Bath," has been the subject of some speculation. De Morgan * suggests that it is the remains of a barrage or dam which formerly extended across the river-branch to Elephantine, or possibly a military structure forming a prolongation of the ancient wall which is seen on the road to Philæ. But the part which remains appears scarcely massive enough to form part of a dam ; a bridge would be more likely. Fragments of inscriptions found in its masonry prove that it cannot be of pre-Roman age, and it may possibly only date from Byzantine times. No trace of the other end of the structure is to be seen on Elephantine, but the rocky spur on that island immediately facing the ruin may well have been the other abutment.

On the hills immediately south of Aswan are numbers of Old Arab Tombs, some of which are of considerable elegance, though falling into decay. These date principally from the ninth and tenth centuries, and have yielded numerous gravestones with Cufic inscriptions; the stones are now in the Arab Museum at Cairo.

Of the ancient Syene and its famous Well,† nothing can be with certainty identified. As will be seen from the short outline of its history already given, the town was the scene of many destructive conflicts, and was probably demolished during early Arab times. The piles of debris and pottery near the English church indicate that a part at any rate of the ancient town was situated slightly south of the modern Aswan.

The "Alabaster Quarry" which is so favourite an excursion with tourists, situated about 3 kilometres north of Aswan, is really a mass of white quartz; though some of it has been extracted, it is far too brittle and intractable a stone to be quarried for any structural purpose.

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et en Nubie," Paris, 1872. The temples were destroyed in 1822 by a former Governor of Aswan, and the material used to build a palace.

* "Catalogue," p. 47.

† In a note to Plate III of Bonomi and Sharpe's "Egypt, Nubia and Ethiopia," London, 1862, it is stated that in a mosaic found at Preneste, Italy, the well is shown near the temple of Syene. It is also stated that there used to be near the Arab village a few stones with hieroglyphics on them, said to be the remains of a temple in which there was a well in which the sun could be seen at midday in summer. Denon, who refers to the cataract district at pp. 208–231 of his "Voyage dans la Basse et la Haute Égypte," London, 1809, suggests that the well was the nilometer of Elephantine

Sandstones and clays, especially the latter, have been largely quarried in the hills south-east of the town ; the clays have been employed as manure, and also to some extent for pottery. Kaolin has also been found in some quantity in the valley which opens out near the quartz mass. The granite quarries will be described further on (see p. 74).

The west bank of the river opposite Aswan is formed by the thickly sand-strewn slopes of the Libyan plateau. The surface of the plateau near the river is broken by irregular hills and wadis ; and the thickly accumulated sand in hollows and wind-shadows renders it uninviting to the pedestrian. The district possesses, however, many points of interest which well repay a visit. The principal hill, Jebel Qubet el Hawa, crowned by a very conspicuous sheikh's tomb, abuts on the river at the point where it takes a turn to the north. This hill, which rises nearly 100 metres above the Nile, contains the famous rock tombs of the Early and Middle Empires, commonly known as "Grenfell's Tombs," after General Lord Grenfell, G.C.B., who opened most of them. The tombs are situated about half-way up the side of the hill, and are approached by two parallel stairways with an inclined plane between them. For a description of these tombs, which have contributed considerably to our knowledge of early Egyptian history, reference should be made to archæological works.* The most important tomb is that of Hirkhuf, which has some interesting inscriptions (first described by Schiaparelli,† and afterwards studied by Maspero ‡ and Erman §) on either side of the door, relating to an expedition into Nubia in the time of King Mer-en-ra (Sixth Dynasty). Near one of the tombs De Morgan relates that there are large pits with bones of rams and crocodiles.

At a lower level than the rock tombs, on the same hill, are the remains of a large Coptic monastery, which was destroyed, according to an inscription in the tomb of Khunes, in 1173 by an expedition of Saladin. These ruins are badly preserved and uninteresting.

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* The tombs are fully described and illustrated in De Morgan's "Catalogue" pp. 143 to 201. See also M. Bouriant, "Les Tombeaux d'Assouan," (Rec. de Travaux, x. pp. 181 *et sqq.*); and Budge, Proc. Soc. Bibl. Arch. 1887, pp. 31–36, and Rec. de Travaux x. pp. 4–40. A shorter description will be found in the guide books, that by Hachette containing also a plan.

† "Una tomba egiziana inedita," Rome, 1892.

‡ "Revue critique," 26me année, p. 358.

§ "Zeitschrift für Aegyptische Sprache," 1892.

The wide sandy gully which runs down to the Nile about 1½ kilometres south of Grenfell's tombs also contains numerous rock-tombs, which are, however, of no great interest; they appear to be late Roman.* On the south side of the gully, however, about a kilometre from its mouth, is the largest and most interesting monastic ruin in Egypt, the monastery of St. Simeon. This monastery, which covers an area of about 9,500 square metres and must have been an important place, was abandoned about A.D. 1290. The ruins still contain numerous frescoes and inscriptions, many of which have been published by De Morgan.† An ancient cemetery exists 200 paces east of the monastery; the bodies were buried simply in the ground, without coffins of any kind, and are very imperfectly preserved. A few stelæ ‡ were found here by Maspero in 1883, and are now in the Museum of Alexandria.

The sandstone-beds around the monastery are highly ferruginous in places, and it has been supposed that limonite was formerly worked here. The stone now visible, however, contains generally far too small a percentage of iron to serve as a useful ore.

III.—The Country between Aswan and Philæ.

The country east of the river between Aswan and Philæ is a complex of bare hills, of which the highest are flat-topped, being capped by sandstone, while those of less height are rugged masses of granitic rocks; the higher plateaux rise over 80 metres above the river. Through this mass of hills, occupying the places where formerly the Nile cut its way, run two main roads between Aswan and Shellal. The more usual road, and the shorter of the two, starts from near the English church and runs nearly parallel to the river, at a distance of about a kilometre from it, till the reservoir dam is nearly reached, when it curves round eastward (to avoid crossing the hills immediately north of Konosso), and reaches the river close to Philæ. The other road, further east, runs along the wide valley

* De Morgan, "Catalogue," p. 128.

† "Catalogue," pp. 129–139. De Morgan gives a full account with plan and illustrations, of this remarkable ruin. A brief description is given in Baedeker's guide book, while in the "*Guide Hachette*" will be found a slightly fuller account, together with a reduced copy of De Morgan's plan.

‡ Bouriant, "Rec. de Travaux," 1888, pp. 181–198.

occupied by the Aswan-Shellal railway. It is not possible to proceed along the river-bank the entire distance, owing to the hills in many places descending abruptly into the Nile; but various side-tracks lead to the different villages from the main road above mentioned. There are eleven small villages between Aswan and Philæ, all situated by the river's edge, called (in order from north to south) SHADIAB, KUTI, JEBELTOGOK, MAHATTA, MESITOT, RASHGUL, ARADUL, ARAKIR, SELAKIA and KOROR, the last-named being about 600 metres north of the dam. These villages present no special points of interest, though some of them are prettily situated. The houses are built of mud-bricks with arched roofs; the scarcity of timber here, as in all Nubia, has driven the people to the particular manner of roofing which they adopt, and the arches are built without centres in a way which indicates a certain skill. The dwellings are, moreover, by no means so small and rude as those of many villages in Lower Egypt. There is no cultivable land worth mention at any of these villages; the inhabitants are mostly employed as boatmen, or as servants in Aswan. The villages BAHR and HAGAB, which till 1902 occupied the bank near KONOSSO, have disappeared since the formation of the reservoir, having been situated below the reservoir-level.

A ride along the usual road from Aswan to Philæ is full of interest. Passing the old tombs already mentioned (p. 35), the road leads along a defile with hills on either hand; those on the west are in many places crowned with mud-brick ruins, most of which are the remains of forts and block-houses. One of the largest of the forts has recently been converted into a coast-guard station; from this building, which is easily recognised by a small round tower at its north-east corner, a fine view of Aswan and the islands near it is obtainable. A walled-in cemetery on the right of the road, 1½ kilometres from Aswan, contains the graves of British soldiers. A little further on, a low embankment of earth running parallel to the track on its east side, represents the débris of an ancient mud-brick wall, portions of which are to be seen still standing near the Philæ end of the road. This wall is strongly built, being about 2 metres thick, and in places 4 metres in height. Nothing is with certainty known of the purpose or date of its construction. It is generally thought to have been a military protection against raids from Eastern tribes, and to have been built by the Romans; but De Morgan considers from the size

of the bricks that it belongs to some earlier period, probably the fifth or sixth dynasty, when Egypt was not absolute mistress of Nubia.*

Very numerous hieroglyphic inscriptions are to be seen on the rocks at various points along the road; near Aswan they occur chiefly on the east, near Philæ on the west, side of the track. No fewer than 211 of these rock inscriptions have been catalogued by De Morgan †; they are nearly all in honour of the cataract-triad, Khnum, Satit, and Anukit, and many of them date from the eighteenth dynasty.

It is from this road, too, that the ancient granite quarries are most easily visited. The nearest of the quarries is about a kilometre south of Aswan, on the east side of the road; here can be seen long lines of the wedge-holes made by the ancient workmen for splitting off the blocks, and there still remains undetached a huge block 28 metres long and over 3 metres wide, perhaps intended for an obelisk. Other quarries can be seen by going south-south-east over the hills from the obelisk, so as to strike the valley wherein the Aswan-Shellal railway runs; these southern quarries, which are more extensive than the one above mentioned, will be described further on.

At a point about a kilometre south of the English cemetery, a branch track leaves the main road and turns sharply off westward through a gap in the hills, to the village of Mahatta, which is about half a kilometre distant.

A little further on, at a point near a small ruin, the main road divides, one portion continuing a little west of south and leading to the dam and the village of Koror, the other crossing the ruins of the ancient wall and continuing on its eastern side to near Philæ. Taking the former branch, the dam comes into view after going about a kilometre and a half along it, the hills on the west abruptly ceasing, but those on the east continue past the dam. It is possible at times to go from the dam to Philæ by a track skirting the bank, but in flood or when the reservoir is full the river covers the foot of the hills and a detour eastward must be made so as to join the other branch of the road alongside the ancient wall. This branch leads past the European cemetery, and turns first eastward past a

* De Morgan, "Catalogue," p. 1. It is however singular that Strabo, who travelled this road in A.D. 24, does not mention the wall. See his description, "Geog." XVII, c. I, § 50.

† "Catalogue," pp. 1–27.

sheikh's tomb, and then southwards towards Shellal. It is just before emerging on to the open ground near Shellal that the best-preserved portions of the ancient wall are seen.

The other road from Aswan to Philæ, through the valley occupied by the railway-line, is of scarcely less interest than that already described, though considerably longer. The start is best made from the railway station, following the line eastward through the cutting, past the Bisharin camp and the junction station into the open valley. A conspicuous sheikh's tomb and a fort crown the prominent hill on the right. To the left is a mass of bare hills of uninviting aspect; those to the north are capped by sandstone, but opposite to Aswan they are mostly of grey glistening schists with red pegmatite dykes coursing up them. The floor of the broad valley consists of sand and gravel in thick deposits, through which pass shallow natural drainage-channels. The road generally taken is along the railway line for some distance; but it is worth while going further east, to examine the deeply eroded gorges which have been cut through the rocks by torrents. An important camel-road leads up one of these gorges and over the hills into Khor Abajaj, where water and a little grazing for camels can be found about four hours' journey from Aswan. * As the great bend in the railway is approached (3 kilometres south of the junction-station) the points of principal interest are to the west of the line. Here will be seen the ancient quarry roads, still marked by dropped stones; if followed up to the hills, abundant remains of the ancient industry will be encountered. We see the inclined planes of earth down which the large stones were rolled, the half-hewn blocks with their wedge-holes, and numerous half-finished pieces of sculpture which were left *in situ* when the work was abandoned. An unfinished sarcophagus lies on the summit of the little hill east of the inclined planes; two others of a similar kind, as well as some other sculptures, are to be seen on the edge of the hill about 400 metres further south.† Near the top of the scarp, about 400 metres still further south, is a re-

* The water occurs in hollows in the granite, at a place called El Hadir (Lat. 24° 5′ 55″ Long. 33° 3′ 20″). I found several large pools here in November 1902, but they probably dry up in summer, as do also the supplies often got by digging in the sand in Khor Abajaj.

† Figures of these sarcophagi and of a large statue of Amenophis III will be found in De Morgan's "Catalogue," pp. 62–63. I have not been able to find the statue, of which only the base is said to be visible; possibly it lies north of the sarcophagi.

cumbent statue of Osiris, lying face upwards. Another similar statue lies on the eastern side of a small granite hill near the ancient wall in about the latitude of the centre of the dam.*

A narrow steep-sided gorge will be noticed on the map to the east of the great bend in the railway. This gorge, or cañon as it might be called, is well worth a visit as exhibiting what erosion-effects can be produced by occasional storms. The rock is extremely hard granite, but has been crushed and sliced up by pressure ; the separated blocks have been removed by short-lived torrents, and many of them still strew the channel leading from the gorge towards the river. The floor of the gorge is strewn with sand, in which, about half a kilometre from the mouth, water can sometimes be got by digging. An Arabic inscription occurs on the rock near the further end of the gorge.

A little north of this gorge, a well-marked camel road leads south-eastward over the hills into Khor Buerat, and thence past Jebel Kurtonos southwards. Another road leads past the mouth of the gorge southwards between the hills into Lower Nubia, but has not been surveyed further than is shown on the map.

The hills south-east of the railway line are mostly of granite, weathered into rounded blocks, with some dykes running through them. Further south they pass into gneisses and schists.

IV.—The Cataract Islands between Elephantine and the Dam.

The group of small islands close to the south-west of Elephantine, consisting of Ismailnarti,† Magrun, Abdunarti, Romnarti, Khashabinarti, Hassannarti, Daunarti, and Isanarti, are mostly rocky, with patches of alluvium and vegetation on their higher parts. They present no special points of interest other than the effects of water erosion shown by numerous potholes. Some of the smaller islets dotted about among those named above show this potholing in a very marked degree.‡ Romnarti is not separated from Elephantine except at high Nile.

* This statue, which was kindly pointed out to me by Mr. E. H. Tabor, appears not to have been previously noticed, and even the local native guides were ignorant of its existence in 1901.

† Arti=island in the Kenus dialect of the Nuba language. The scale of the reduced map on Plate I is too small to permit of the names of the minor islands being shown ; these names are however all indicated on the $\frac{1}{10,000}$ map of the district, published separately in 6 sheets (see footnote on p. 22.).

‡ One of these smaller islets, situated a little south of Elephantine, has recently been made the subject of detailed study by Prof. Brunhes. See p. 74. foot note.

AMBUNARTI, ARABINATI, and GUBALNARTI form a single low straggling group at low Nile, most of their surface being formed of sand and silt, through which the granite rocks protrude in places. Ambunarti is the only one of the three which possesses any cultivated land, and that only a small area of about 3 feddans. Khurwanarti (so called because of its bearing a small castor-oil plantation), Shebkatot, and Mulhumnarti, are, like the foregoing, low-lying islands of silt with rocky patches, mostly covered at high Nile.

SALUJA ISLAND (which forms a single island with Mulhumnarti at low Nile) is the first island south of Elephantine which rises to any considerable height. It consists of a central granite-hill, the summit of which, 21 metres above the flood-level, bears a high telegraph post, and around which are lower tracts of alluvium with occasional rocky protuberances. Some small patches of the alluvium are cultivated and a larger area bears traces of former tillage.

A group of small rocky islands exists near the west bank between Saluja and Sehel. Of these, the two largest bear the names of APTOK and SEMDENARTI. Aptok * is a steep rock which can only be ascended from the west side. Semdenarti bears two small patches of cultivation, but is mostly of bare syenite.

SEHEL, the largest island north of the dam, is nearly rectangular in plan, being about a kilometre in length from north to south, and a little over half a kilometre in breadth. At low Nile it is united with several surrounding islands to form a more extensive mass, as will be seen from the map. The greater portion of the island is formed of bold granite and gneiss hills, rising between 30 and 40 metres above the river. The hill north of the central mass is called Jebel Aiman, while two other hills to the south are named Jebel Kudi and Jebel Birbe respectively. Between the hills and along the east and west sides of the island are some flat alluvial tracts, cultivated in places, but often broken by rocky protuberances. There are two villages on Sehel; the southern one is called by the same name as the island, while that north of it is called GARBA; both these villages face to

* LUCAN "Pharsalia," lib. x and SENECA "Nat. Quæs." lib. IV, Cap. 2, mention an inaccessible island, called *Abaton*, at the cataract. Can Aptok be a survival of the name? This would involve the supposition either that the name has been shifted to another island, or, what is not impossible, that the cataract has retreated considerably since the beginning of the Christian era. Traces of water action exist on the rock at a level considerably above that of the highest Nile of modern times.

the west. Names are also given to three other localities on the island which are not occupied by villages; these are KENISGELI, a narrow alluvial tract (cultivated at low Nile) at the north-east corner between Sehel and Nunarti, GABANUR, an uncultivated flat alluvial tract on the west near Jebel Timan, and MOLTINEK, a cultivated area between Jebel Birbe and the central hill-mass.

Sehel appears to have formerly possessed two small temples, but only fragments remain. One of them, on the east of Jebel Kudi, was erected by Amenophis II.; the other, at the foot of the west side of the central hill-mass, was Ptolemaic. We learn from the inscriptions that the ancient name for Sehel was Satit, and that the godess Anukit was regarded as its special protector. Sehel contains many inscriptions on its rocks, no less than 233 having been catalogued by De Morgan.* The inscriptions are not, however, all of equal importance, many being insignificant, while others are illegible. Visitors from the sixth to twentieth dynasties have engraved their names and those of their sovereigns—Pepi, Usertesen, Amenophis, Thothmes, and Rameses. In some cases the inscriptions record interesting facts. Usertesen III. made a canal at Sehel for the vessels employed in his Nubian expeditions to ascend the cataract; and the canal was subsequently improved by Thothmes I. and Thothmes III. It seems impossible to trace the site of this canal at the present day. De Morgan thinks it was possibly the channel east of the island, between Sehel and Mahatta, Sehel having formerly formed part of the mainland; but this suggestion would appear to be negatived by the size of the canal given in the inscriptions, for it was only 150 cubits † in length, 20 cubits in breadth, and 14 cubits deep, and thus quite a small affair.‡ Moreover, it would appear, from the injunction of Thothmes III., "the fishers of Elephantine shall cut this canal every year," that the cutting was more probably through silt than through rock.

Near the top of Jebel Birbe is an inscription recording a seven years' famine in the eighteenth year of a king whose name has not been with certainty identified. It has been thought that the cartouche is that of Tosorthros, a king of the third dynasty, but the

* "Catalogue," pp. 84–102.

† The cubit was equal to about 525 mm. GIRARD, "Description de l'Égypte," T. III.

‡ PETRIE, "History of Egypt," Vol. p. 179.

style of the inscription shows it to be of very much more modern (Ptolemaic) date.*

The greater number of the inscriptions of Sehel are on the rocks of the south part of the island;† those of the north, and of the adjoining islands, are barren of records.

Four islands become continuous with Sehel at low Nile, viz., NUNARTI, AISANARTI, ALINARTI, and KULNESOK. Nunarti is a rocky mass at the north-east corner of Sehel. Aisanarti is a straggling mass of alluvium and rocks on the west; one tract is cultivated and is permanently above the river level, and another strip is cultivated on the slope as the river descends after the flood. Alinarti and Kulnesok are rocky masses south of Sehel, that of Kulnesok rising to a considerable height.

MESITOT ISLAND, named after the small hamlet on the mainland, is a triangular island, mostly rocky; it is situated at the south-east corner of Sehel, from which it is permanently separated by a narrow rocky channel. The cross channel of the river south of Kulnesok and Mesitot islands follows the course of a large dyke, the continuation of which can be easily traced on the mainland to the east.

West of Kulnesok, around the Bab Hemedai, are a large number of small rocky islands, of which the three largest are called HARUFINARTI, KHAUADULARTI, and ARTINASILARTI.

From the south of Sehel to the reservoir dam stretches a large group of unimportant islands, of which the names will be found on the large-scale map‡. The greater portion of them are covered when the stream is in flood, but some, such as UGARTI, TURGARTI, SABINARTI, and HABSARTI, rise permanently above the waters. With the exception of UMBERKUL, on which a few small tracts are cultivated at low Nile, none of these islands bear habitations, cultivated lands, or archæological remains. The channels between them are mostly impracticable for boats at low Nile, and when the river is in flood the waters are so turbulent as to require great care and exertion in getting even a small craft through them. The broad channel west of the islands is however fairly navigable at all times of the year.

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* BRUGSCH, "Die biblischen sieben Jahre der Hungersnoth," Leipzig 1891. See also DE MORGAN, "Catalogue," pp. 78–82.

† Inscriptions are especially numerous on Jebel Birbe.

‡ See footnote, p. 41.

The islands of AMINARTI, UNGARTI, and THIRMOSIA (the last-named of which is crossed by the dam) are only separated from the east bank in certain states of the river. They are irregular low granite masses with alluvial patches and are mostly covered by water at high Nile. That part of Thirmosia which lies south of the dam is of course completely submerged when the reservoir is full.

V.—THE WEST BANK BETWEEN THE MONASTERY OF ST. SIMEON AND THE DAM.

The west bank of the river is formed by a continuous escarpment of sandstone, with granite and other eruptive rocks cropping out at its base. It is only at a few points that the foot of the escarpment is covered with more than a very narrow strip of alluvial land, and this, like the whole face of the scarp, is thickly covered with desert sand. The sandstone plateau has an average height near the river of about 50 metres above flood-level; it is intersected by several wadis running down to the river, all these hollows being sand-traps in which the blown material of the desert is accumulated. The edge of the bank, due to the irregularities both of the hardness of the igneous rocks which fringe the water, and of the currents which sweep past them, is of very broken outline; but speaking generally, it runs about south-west from near Elephantine to Saluja Island, then turns south, and veers a little east of south from the Bab Hemedai to the dam.

Owing to its naturally inhospitable character, the west bank in this locality was not till last year inhabited by more than a few Nubians, who lived in the tiny hamlets of SEHEL GOBAN, NEGAR AHMED and NEGAR EL HAGAR. When the new lock at the Bab Hemedai was constructed in 1902, these hamlets rapidly increased in size to accommodate the workers, and they are now fairly large villages. The inhabitants cultivate narrow strips of land at the extreme edge of the bank. They wage continual warfare against the sand, which is perpetually tending to envelop their houses and crops. Near Sehel Goban, as the Nile goes down, large pools are left in the rocks, and as the suspended matter settles and leaves the water clear these frequently present a very beautiful appearance, surrounded as they are with romantic-looking rocks.

There is only one spot in this portion of the desert which is known to contain any antiquities—this is a conspicuous mass of sandstone, described by De Morgan * under the name of the "rock of Tingar." It is situated on an eminence near the tomb of Sheikh Othman. According to De Morgan, the place was anciently venerated, and was probably dedicated to Khnum, as the thirty-nine inscriptions on and in it are nearly all names of priests of that deity. The *débris* of a stela of the eighteenth dynasty found here appears to bear reference to an expedition of Queen Hatasu to the land of Punt.

VI.—The Nile Reservoir.

A length of about 225 kilometres of the Nile Valley above the village of Koror has recently (1898–1902) been converted into a reservoir by the construction of a masonry dam with 180 sluices across the stream near Koror, as shown on the map. The dam, built of granite masonry, runs straight across the river and its islands, in a west-south-westerly direction. Its length is 1996 metres, its height above low Nile 24 metres, and its greatest breadth at base 26 metres, diminishing to 7 metres at the top. The 180 sluices, which are mostly situated in the western half of the dam, are each 2 metres wide, and are mostly seven metres high, though some at higher levels are only of half this height. The masonry is 5 metres wide between the sluices. The sluices are worked by hand-crabs placed on the top of the dam. They run on rollers to diminish friction, and are kept watertight by an ingenious arrangement which allows for wear.† The object of the dam is to increase the summer discharge of the river at time of low Nile, by gradually releasing during that period the water stored earlier in the year. The dam has no effect on the Nile flood,‡ being constructed in such a way as to preserve the full

* "Catalogue," pp. 126–128, De Morgan gives illustrations of the place and its inscriptions.

† For a full account of the construction of the dam and its sluices, reference should be made to the papers by Mr. Fitzmaurice and Mr. Wilfred Stokes in the "Proceedings of the Institution of Civil Engineers," CLII, pp. 71–155.

‡ There is, says Sir H. Brown (in the discussion on Mr. Fitzmaurice's paper above mentioned) a common delusion that the dam gives the power of moderating high floods and of improving low floods, whereas in reality it does no such thing. Its function is simply to give a better supply in summer to sugar cane and cotton crops, which are not the food-crops of the people. Scarcity of food crops will still follow on a low Nile, and the dangers of high floods will not be in any way averted by the dam.

original waterway when all the sluices are open; the flood discharge (July to December) goes through the dam, practically unobstructed. In December, when the river is practically free from silt, but before its level has fallen sufficiently to cause a partial abstraction of its water to be felt in Egypt, the sluices are partially closed so as to diminish the natural discharge past the dam, and cause a corresponding accumulation of water in the reservoir. The storage goes on till February, when the reservoir is full to its capacity of 1,000 million cubic metres, and the sluices are sufficiently open for the dam to be again without effect on the natural discharge. In May, when the natural discharge of the Nile becomes usually so low as to cause dearth of water in Egypt, the stored water is gradually discharged, thus augmenting the natural water supply during May and June and preventing the evils which would result from so low a discharge as the river would otherwise have. The diagrams below exhibit graphically the effect of the reservoir on the water levels and discharge of the river in an average year; Fig. 1 shows the water levels in the

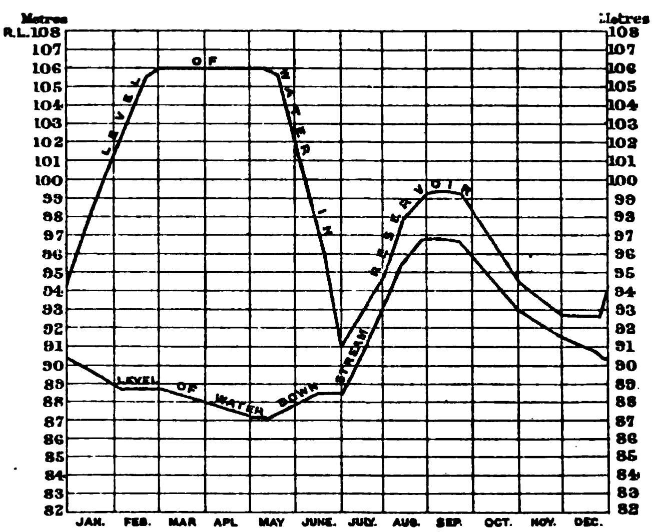

Fig. 1.—Diagram showing the variations in water-level above and below the dam during the filling and emptying of the reservoir.

reservoir and on the down-stream side of the dam, while Fig. 2 exhibits the effect of the dam on the Aswan gauge and on the discharge of the river. From this last diagram it will be seen that the summer level of the river is raised some 20 centimetres, and the discharge is increased during May and June by about 200 cubic metres per second, by the use of the reservoir.

Though the dam has been built for the good of the country down-stream of it, and its effects on that side in consequence form the main

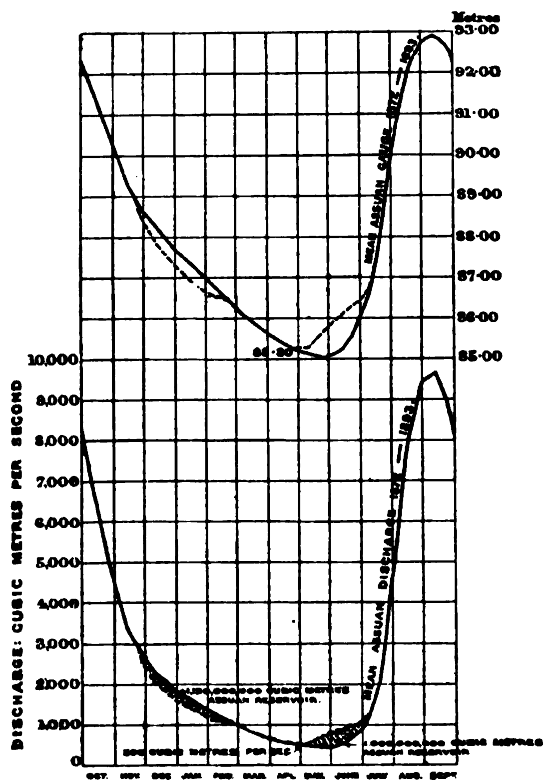

Fig. 2.—Diagrams showing the influence of the reservoir on the levels and discharge of the river during an average year.

feature of consideration, it has also been necessary to provide for its effects on navigation and on the country above it.

The dam, as will be seen, completely bars the river to navigation, and it has therefore been necessary to supplement it by cutting a canal along the west side so that vessels may pass. This canal is controlled by four huge locks, which when the reservoir is full have each a lift of 5 metres. The natural channel above and below the canal has been improved by blasting out obstructions, and a separate lock, with a maximum lift of 2½ metres, has been constructed to enable boats to pass the Bab Hemedai. There is now an easy passage up and down the cataract at all times of the year.

The country south of the dam for a long distance is flooded each year as the reservoir is filled, the depth of flooding being of course a

maximum near Shellal and gradually lessening up-stream. When the reservoir is full the water-surface coincides with the level of the top of the bank about Dakka; below this point the lands are submerged and most of the houses of the natives have collapsed in consequence. The Government has compensated the natives financially for the damage to property, and many of them have removed to other villages below the dam with the capital thus provided; others have built new dwellings at higher levels on the desert bordering the river, and these cultivate the banks each year as the river-level falls. Many of the date-palms fringing the old river-bank were destroyed by the filling of the reservoir. The railway station of Shellal has been removed northwards so as to be above the reservoir level; the goods traffic on the Aswan-Shellal railway will doubtless be reduced now that it is possible to load boats at Aswan and sail them up the cataract by way of the canal and locks, but the line will continue to be worked, and forms a ready means of reaching Philæ from Aswan.

The islands of Awad, Biga, Philæ, and El Hesa, being situated at the head of the reservoir, have their lower parts flooded each year. The flooding was a serious matter in the case of Philæ, and the insertion of new foundations under the numerous temples became necessary in order to avoid their collapse. This work, the charge of which was entrusted by the Government to the writer, was carried out in 1901–1902; the temples are now secure against subsidence, and the only effect of the annual flooding is to render them inaccessible except by boat for a few months of the year.

The Islands South of the Dam.

Awad is a large island situated immediately south of the dam in the western portion of the river. At low Nile it is of a trapezoidal shape, being over 1,200 metres in greatest length and about a kilometre in width. The greater portion of the island is occupied by low bare hills, of which one is capped by sandstone, the others being all of granitic rocks rising in places over 40 metres above the river. Round the edge of the island, at the feet of the hills, are tracts of alluvium, which until the construction of the reservoir bore four villages and a small amount (about 4 feddans) of cultivation. These villages were Balli and Ungahilla on the west, and Fagirtogog and

Shemadul at the south-east corner of the island; with the filling of the reservoir in 1902 the old villages disappeared, being almost entirely below the reservoir-level, but Balli and Fagirtogog have been rebuilt on the hill-slopes at a higher level. Only the central granitic mass rises above the surface of the reservoir when full, so that the island as then exposed is much smaller than in the natural state of things. Awad appears to be altogether destitute of archæological remains.

Shash and Ernab islands are rocky masses north-east of Awad. They bear some patches of alluvial mud when the river is low, but neither habitation nor cultivation exists on them. Ernab is completely covered when the reservoir is filled; the central rocks of Shash, however, rise permanently above the waters.

The mass collectively known as Biga consists of three principal islands, which are only connected at low Nile. Biga proper is the southernmost and largest of the three; it consists almost entirely of granite hills rising in places over 60 metres above the high Nile level, but there are a few alluvial patches, and until the reservoir was made there were two small villages. The eastern village, called Biga, is at a high level and consequently unaffected by the reservoir; the other, Ala Shema, on the west side, was lower and has been destroyed. No land was cultivated on the island except a small patch at Ala Shema.

Biga, under the ancient name of Senernt, appears to have been a sacred place in comparatively early times, being rich in inscriptions, some of them dating from the twelfth dynasty. The jubilee of Rameses II. was celebrated here by the prince and high priest Khor Khamuas.* Besides the rock-inscriptions, the island possesses some interesting ruins, consisting of the remains of an ancient quay-wall and steps, a Ptolemaic temple, and a Roman arch, all of which are situated close to the village and are visible from Philæ. These ruins (except the quay and steps) are above the reservoir level and will probably be unaffected by the rise of water. Behind the ruins are the remains of two statues (Amenothes II. and Thothmes III.).

Salib and Agilkia, the two northern islands of the Biga group, are smaller granite hills with fringes of Nile deposit. They have neither

* Brugsch, "Egypt under the Pharaohs," vol. II, p. 115.

habitation nor cultivated lands; Salib has a single unimportant rock inscription.

The island of KONOSSO, due east of Agilkia, is only separated from the mainland during high Nile and when the reservoir is filled. It is a small but conspicuous mass of rather high granite rocks, with no less than sixty-five inscriptions, and appears to have been a place much venerated in ancient times. The greater portion of the inscriptions are dedicated to Khnumu, lord of Kebhu. Kebhu is the general name given to the cataract in ancient inscriptions, but it is possible that it refers here specially to Konosso, where a small shrine dedicated to the god may once have stood. Among the inscriptions are some of Amenophis III. and Thothmes IV. (eighteenth dynasty).

So much has been written concerning the beautiful temple-covered island of Philæ, that a very brief mention of it only need be given here. The island is about 460 metres in width. At its south point is a low granite hill, which is the only part uncovered when the reservoir is full. The temples now standing are mostly Ptolemaic and Roman, though one is older, and as historical landmarks they are far behind the great structures of Thebes in interest. The so-called "Kiosk," really the temple of Trajan, is one of the most elegant structures in Egypt. In order that the partial flooding of the temples by the reservoir in the months of February to May should not cause destruction of the ruins by subsidence new foundations were inserted under them in 1901-1902; at the same time the remains of an unsightly Coptic village, built of crude brick, was removed to prevent its forming a salty destructive sludge when submerged. It had long been suspected, from a cartouche existing on the inner face of one of the columns of the Ptolemaic temple of Isis, that temples had existed on Philæ at least as early as the twenty-sixth dynasty. This suspicion was confirmed during the excavations for the underpinning, when the foundations of older structures were found under the existing temples, and a slab bearing the names of Amasis II. was dug up from under the Mammiseum.

The island of EL HESA (sometimes called Geziret el Atik) is the most southerly and the largest of all the cataract islands. At low Nile it is nearly 2½ kilometres long and 1,200 metres wide; in plan it is somewhat pear-shaped, the point being southwards. By far the greater portion of the island, and in fact all of it that remains visible when the reservoir

is full, consists of hills of granite and other eruptive and metamorphic rocks, which are traversed by numerous dykes. The highest point, near the centre of the island, is over 60 metres above high Nile level. The low-lying parts of the island, peripheral to the central mass and only uncovered when the reservoir is emptied, are covered with patches of alluvium, strips of which (of an aggregate area of about 15 feddans) were formerly cultivated at and near the south point. At the north-west corner is a columnar granite rock, near which an alluvial tract of about 3 feddans was formerly under tillage. The villages which existed prior to the making of the reservoir were called GARBA (at the north-east corner), SULUKOLI, ANGARNASHE, IKESHEMA (on the south-east), ARTINOG (at the south point), and KHOR (on the west). Most of the old houses of these villages disappeared on the first filling of the reservoir, but GARBA, ANGARNASHE, and KHOR have been rebuilt at higher levels, and a new village, called Warrad, has sprung up near the centre of the east shore of the island. Between Sulukoli and Angarnashe a conspicuous granite hill, surmounted by a cairn marking a sheikh's tomb, approaches close to the river. A gully formed by the weathering-out of some soft basic rocks affords an easier path to Khor from here than going round the southern hills. Hesa does not appear to have been of importance in ancient times; there are, however, (near the south point) some fragments of columns and other sculptures which seem to point to the former existence of a temple or chapel there.

VIII.—THE EAST RIVER-BANK SOUTH OF THE DAM.

From the dam southwards to near Konosso, the river is bordered by the hills which form the southern extremity of the great hill-mass lying between the present and former beds of the Nile. A strip of lower alluvial ground of varying width runs along the foot of these hills, but is submerged and impassable when the reservoir is full. About 600 metres south of the dam a gully cuts through the mass, and a track runs from the river by way of this gully to join the ordinary Shellal road near the sheikh's tomb mentioned on p. 40. This gully is of interest as marking a line of fault; the hill to the north of it is a sandstone plateau with granite below, while on the south the base of the sandstone is about 25 metres higher, and the sandstone

forms only a small cap on the igneous hill. Several dykes cross the gully near the fault.

Opposite Philæ is a wide alluvial stretch forming the mouth of the old Nile-bed. Here, till recently, stood the small villages of Bahr and Hagab, but they disappeared at the first filling of the reservoir, and have been replaced by a new village, called Jebel Shishi, at the foot of the hills south-east of the new Shellal station.

The south boundary of the old Nile-bed is formed of hills of crushed granite and schists. They continue south, closing in gradually to the river-edge; they rise to about 40 metres above the high Nile level. There are some ancient water-marks visible on the rocks north of Hafir; these can be followed round for some little distance at 114.6 metres above sea-level, thus apparently showing the river to have risen formerly at least 18 metres above its present flood-level.

The villages of Hafir, Juani, Baggar, Bab, Mishek, Tichi, and Ajarma, which formerly stood on the river-bank at the foot of the hills, have disappeared along with many of their palm-trees, owing to submersion by the reservoir, and the bank can be only traversed with difficulty when the reservoir is full, as the water comes on to the rocky slope for nearly the entire distance. Near Hafir was the old post office and railway station of Shellal, and the bank here formed a busy scene owing to its being the berth for the Government and other steamers plying between Shellal and Wadi Halfa. Steamers will now load north of Aswan and ascend the cataract by means of the canal and locks on the west of the dam. The river-bank here was always narrow, and only about 27 feddans of land were under cultivation in the whole of the six villages above-mentioned. The inhabitants have mostly removed to other parts since the flooding of their villages, but a few have constructed dwellings at higher levels and still remain near the sites of their old houses. In addition to the rebuilt hamlets which retain their old names, a new one, called Abd el Asiu, has recently come into existence near the white-towered mosque known as the "Gama Bilal."

The antiquities in this district are few, and with the exception of a rock inscription of the sixth dynasty discovered opposite the south end of El Hesa in 1892 by Prof. Sayce,* apparently all of the Arab

* "Rec. de travaux" XV, p. 147.

period. The most interesting of the ruins is an old fortress, the thick rubble walls of which course up the hill-side behind the village of Bab and form an enclosure with towers on the top. There are no inscriptions observable at this place, which may have been the "El Kasr, the first city of Nubia, one mile south of Belak (Philæ)" mentioned by Ibn Selim el Aswani,* and thus probably was inhabited in the seventh century. There are two mosques, both in ruins, situated a little further south. The northern one is on the hillside at Mishek; the other, conspicuous by its white minaret, is about half a kilometre further south. These mosques appear to have been originally Coptic monasteries; the stones of the southern one are partly derived from temples on Philæ. About midway between the two mosques a small patch of a very beautiful diorite occurs in the schists on the hillside.

Just beyond the south limit of the map a prominent peak overlooks the river at the village of Kullutot; this hill marked the southern extremity of the cataract survey. Immediately south of it is a very interesting cañon-like gorge in the granite rocks, with basalt-dykes running along its floor.

To the south of the dam the west bank continues with the same characteristics as it bears further north, the scarps of the desert descending close to the water's edge, with only a narrow strip of alluvial ground here and there between them and the river. The sandstone lies at higher levels as one goes north, and retreats from the river so that nothing but igneous and metamorphic rocks are visible from the Nile after passing El Hesa. Gullies, mostly full of blown sand, descend here and there, and just south of El Hesa there is a place where the scarp retreats sufficiently from the river to leave an alluvial tract about 700 metres long and 200 metres wide fitted for cultivation. Here stood till recently the large village of Tengar, with about 12 feddans of cultivated land. The reservoir has destroyed this village, and many of the palm-trees near it, and new houses have been built on the hill-slopes. There are, I believe, no archæological remains along this portion of the river bank.

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* Quoted by Makrizi; see Burckhardt's "Travels in Nubia," Appendix III.

CHAPTER III.

THE GEOLOGY OF THE CATARACT.

GENERAL OUTLINE OF THE GEOLOGICAL STRUCTURE OF THE DISTRICT.

As the Nile Valley is followed up from Cairo to Aswan the deserts on either side are seen to consist of an unbroken series of sedimentary strata. Corresponding with the general gentle north-westerly dip of the beds, the Eocene deposits give place as the river is ascended to Upper Cretaceous strata, the lowest member of which, the Nubian sandstone, is practically the only rock met with from near Edfu to Aswan. But when we reach the Cataract an entirely new aspect is given to the scenery by the outcrop of a large boss of igneous and metamorphic rocks beneath the sandstones. This mass of igneous and metamorphic rocks extends up the river nearly as far as Dabod (some 22 kilometres south of Aswan), so that only its north end is seen in the Cataract area. The principal rock is the well-known red syenitic granite which has served for so many of the early Egyptian monuments. But this is by no means the only igneous rock met with. Apart from the considerable variations which the syenitic granite itself shows, we encounter, especially near the periphery of the outcrop, a series of older gneisses and schists. In addition, dykes of granite, pegmatite, quartz-felsite, porphyrite, and basalt penetrate the mass in various directions, and laccolites of dolerite and diorite, now crushed into hornblende schists, are encountered in the granite in one or two places. How great the influences of these dyke-rocks have been in determining the position of the river-channels will be apparent from the geological map. The entire mass has been subjected to enormous earth-thrusts, so that in many places we find granites altered into gneisses, dolerites into schists, and so on, while the number of small faults is legion. The cataract islands are almost entirely formed of igneous rocks. But in the deserts on either side

these are overlain by the Nubian sandstones and clays, which, from the generally undisturbed state of their strata, are at once seen to have been deposited long after the forces which crushed the underlying rocks had ceased to act. The igneous rocks are, therefore, far older than the Cretaceous period. But there are not wanting evidences of some earth-movement *after* the sandstones and clays were deposited, for in several places faults involve these along with the older rocks.

The wide valley, filled with sand and gravel, which runs east of the Nile between Philæ and Aswan will at once strike the eye on looking at the geological map. It is beyond doubt a former course of the river, and the natural inquiry as to what brought about the change in the river's course is full of interest. As will be seen further on, the change may possibly be connected with the faults in the Nubian sandstones already referred to.

In our discussion of the Cataract geology it will be well to consider in order :—

I.—The recent deposits (*a*) aerial (blown sand), (*b*) fluviatile (Nile gravels, sands, and muds).

II.—The Nubian sandstones and clays, and their relation to the igneous and metamorphic rocks.

III.—The igneous and metamorphic rocks themselves.

IV.—General conclusions, with especial reference to the dynamic evidences and physical geology.

In following the geological description reference should be made to the geological map on Plate II. and to the sections on Plate XII.

I.—The Recent Deposits.

(*a*) Aerial deposits (blown sand).

Wind-borne desert sand forms extensive deposits on the western bank of the river at the Cataract, frequently swathing the faces of the scarps which limit the valley. There is also a certain amount of the same material accumulated at some points on the eastern side. But the prevailing winds come from the north-west, and the river seems to form, generally speaking, an effective barrier to the transport of the sand across it; the bulk of the load of sand carried by the wind is dropped in the wind-shadow formed at the western side of the valley.

ɔT.

Plate II.

INDEX TO COLOURS

	G.D.	*Diorite*
	Sch.	*Micaceous and Hornblendic Schists*
	Pg	*Pegmatite*
ite	F	*Felsitic Dykes and Intrusions*
te and Gneiss (South end of map)		*Dykes of Diorite – Porphyrite, Basalt, etc.*

— — — *Faults* —·—·— *Section Lines*

Scale 1 : 20,000.

500 1000 1500 2000 Metres

at the Aswan Nilometer during Survey was 4p. 19k. R. L. 86. 75. m.

Survey Dept. Cairo 1907.

The accumulations of blown sand have an ochre-yellow colour, which inclines to golden in the strong light of the sun. The grains are remarkably uniform in size, being generally about 1 millimetre, or rather less, in diameter. The wind acts as a natural classifier into sizes; the coarsest grains are found near the tops of the dunes, from which the finer particles are blown away and dropped on the lee-side. In shape, the grains are all remarkably well rounded, being in fact converted into miniature pebbles by long friction against each other (*see* Plate III., Fig. 1). Their yellow colour is quite superficial, being due to a thin surface-film of iron oxide. The latter is at once removed on treating with warm hydrochloric acid, leaving the quartz grains of snowy whiteness. Apart from the iron oxide film, the sand is practically pure silica, though it contains occasional grains of felspar and calcareous matter.

The origin of the blown sand of the Lybian Desert is generally thought to be from the disintegration of the Nubian sandstone which forms such large areas on the southern deserts. While this is no doubt correct as regards the sands of Nubia and the Cataract, it is obviously insufficient as an explanation of the dunes in the north unless a change in the prevailing wind has taken place. For, as already stated, the prevailing wind in Egypt has a north-westerly direction, and there is no Nubian sandstone in the valley north of Qena. We may, therefore, suppose that the blown sands of the northern parts of the desert have arisen from the breaking up of other more recent sandstone beds; sandstones of late Tertiary age still exist near Cairo, and may once have covered a far greater area than at present.

Blown sand has been used to some extent on subsidiary portions of the reservoir works as a constituent for mortar. Its remarkable cleanness leaves nothing to be desired in this respect, but the regular sizing of its grains and their roundness renders it inferior, as a mortar material, to the more angular and more irregularly sized sand which is formed by the dry disintegration of granite (*see* p. 64).

(*b*) **Fluviatile deposits (gravels, sands, and muds).**

Ancient gravels.—In the dry valley between Shellal and Aswan are thin beds of coarse gravel. The pebbles range up to 15 or 20 centimetres in diameter. The composition and high degree of rounding of

the pebbles show that these gravels have originated from the disintegration of igneous masses and long rolling in water. They are doubtless remains of the Nile branch which formerly ran through the valley. The fact that they generally cap slight eminences seems to be due to the protective action of the large pebbles on the finer material (ancient silt) below them, which is thus hindered from being removed by the wind and rain.

Older mud deposits.—The higher-lying deposits of river-sand and mud which frequently exist behind the villages, between the latter and the hillsides, are relics of the time when the Nile flowed at a higher level than it does to-day, before the cataracts had been eroded down to their present state. The general nature of these deposits is similar to that of the modern ones presently to be described; but they differ in frequently containing more calcareous matter and some nitre. The calcareous material is in the form of friable tubes, generally one to two centimetres in diameter, and often as much as ten centimetres in length. The banks are in places quite white from the abundance of these stem-like masses strewing the surface; as they are harder than the sandy accumulation below, the latter is more readily removed by the sand-laden winds. Professor Judd, who found similar tubular and knot-like calcareous bodies in the alluvium of the Delta, considers that they were formed by the deposition of calcium carbonate on the rootlets of plants.* The nitre which the banks frequently contain doubtless originates from the decomposition of animal matter, the banks commonly forming the latrines of the villages. It is the presence of this nitre which explains the occasional local employment of the ancient muds as a manure.†

Ancient clay.—During some excavations for laying a new siding to the east of Aswan, a deposit was met with, a few inches below the sandy surface, of a very fine compact chocolate-brown clay. This substance was of such great compactness that it could be cut and shaved with a knife, and the cut surfaces were shiny. It must have arisen by the deposition of alluvial matter of extreme fineness, in still water. I am inclined to think that its origin is to be traced to the time when the Nile forsook its eastern channel, a back-water and

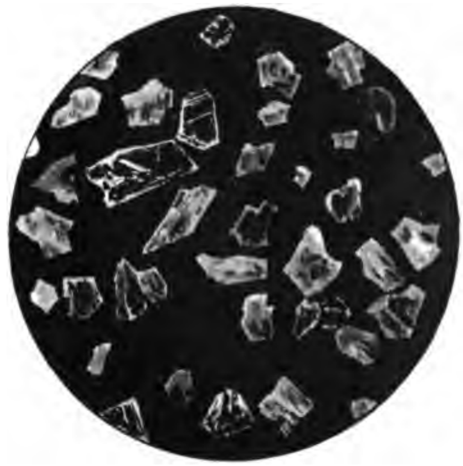
* JUDD. "Second Report on Specimens of Deposits of the Nile Delta," Proc. R. S., Vol. 61, p. 34.

† For an account of the use of this material, known as *sebakh kufri*, as manure, see FOADEN, "Journal of the Khedivial Agricultural Soc.," 1903, p. 10.

PLATE III.

1

2



3

4

1. Typical Grains of the Wind-borne Sand of the Desert, viewed by reflected light, x 12. Well-rounded quartz-grains, averaging about 1 mm. diameter.

2. River-Sand, by reflected light, x 35. Sharp angular grains, of quartz, felspar, hornblende, garnet, magnetite, etc., averaging about 0.25 mm. diameter.

3. Nile-Mud, crushed between the fingers and examined in a film of oil by transmitted light under a high power (x 100). The larger grains are chiefly quartz, decomposing felspar, hornblende, magnetite, etc.; the finer particles consist partly of the same minerals and partly of kaolinic and organic matter. The grains range in size from $\frac{1}{10}$ mm. down to the smallest particles visible under the power employed.

4. Nubian Sandstone, in thin section, by transmitted light, x 35. Angular and partially rounded grains of quartz, with a little felspar (derived from igneous rocks), cemented by a small amount of calcareous and clayey matter. There are numerous small pores between the grains

Bemrose, Collo., Derby, Eng.

lagoons being formed in which the fine sedimentation could go on undisturbed.

Modern river-sand and mud.—The silt of the Nile may be broadly divided into two forms, which differ mainly in fineness of grain. The first and coarser of the two forms is that which is deposited in water running with a moderate velocity, forming sand-banks in the river-bed. The second is the ordinary Nile "mud" which accumulates in basins and at points on the bank where the stream is sluggish. We may designate these two forms by the terms "river-sand" and "Nile mud" respectively; but it should be emphasised that the latter name does not imply any admixture of kaolinic matter, from which all the silt of the Nile, with the exception perhaps of the very finest slimes, is indeed practically free. The term "Nile mud" is one which is commonly used, and is convenient and distinctive; but it simply means any very finely divided rock material brought down by the river, without reference to its chemical nature.

The *river-sand*, which forms low banks fringing the sides of the stream and many of the Cataract islands at low Nile, is of a pale brown colour. It forms, when freshly deposited, fairly firm ground; but on exposure to the sun as the river falls, it dries into a loose incoherent mass, into which one sinks as one walks, while it is readily blown about by the wind. It thus differs strongly from that finer deposit which we call Nile mud, in that it is incoherent on drying. Examined microscopically, it is seen to consist of decidedly angular grains of quartz, felspar, hornblende, garnet, magnetite, and other minerals derived from igneous rocks (Plate III., Fig. 2.) The grains average 0.2 m.m. in diameter. From the varying colours of its constituents, a pinch of this sand placed on a visiting card forms an extremely pretty microscopic slide for examination by reflected light under a low power; many of the grains appear like flashing diamonds, rubies and emeralds. The sizing of the grains is very uniform, running water being even more efficient as a sizing agent than the wind. An interesting observation may be made when the river is low and its surface slightly agitated by the wind; at such times there frequently extends a narrow band of dark leaden-grey metallic-looking sand, covering the surface of the bank a few centimetres from the average water-line. If this be scraped off and dried, it will be found to be strongly magnetic, and consists, in fact, as its specific gravity and a microscopic examination tell us, of magnetite. At certain times one

may select a bucketful of nearly pure magnetite in a few minutes by scraping the surface of the low shelving bank in this way. The sand-bank which formed on the east side of Philæ in the summer of 1902 yielded an abundant supply, but probably any other of the Cataract islands would do equally well. The separation is due to the gentle lapping of the water over the surface of the bank, whereby the lighter minerals are slowly washed out and the magnetite is left at the extreme limit touched by the water. A similar separation of hornblende may be noticed at some points, but is less marked owing to the lower density of that mineral as compared with magnetite.

By *Nile mud* is signified that material, brought down in suspension and deposited by the Nile, which coheres on drying into a tough solid mass. It embraces all the finer material which is deposited from still or slowly flowing water in natural pools, artificial basins, or canals. While the river-sand last described is firm to the foot immediately after deposition, Nile mud when freshly deposited is a soft, sticky mass into which one easily sinks. Exposed to the sun, mud deposits dry slowly, with formation of a network of large cracks; when thoroughly dried, it forms, however, very firm ground. It is the finer variety of Nile mud which is so valued a constituent of the "red water" in irrigation, acting as a manure chiefly by reason of its richness in organic matter. The toughness and hardness of the material when dried is taken advantage of in the manufacture of native unburnt bricks. For this purpose a slurry is formed in a shallow pit, and left for a few days, after which it is moulded by hand in wooden frames. The bricks, which when first moulded have only just enough solidity to retain their shape, are left out in the sun for a fortnight or more to dry, after which they are laid in a mortar of similar mud. It is essential that a sufficient time be allowed for thorough drying; cases of collapse of houses due to the use of insufficiently dried bricks have frequently occurred. But once properly baked in the sun, the mud bricks have a surprising resisting power. Walls of this material have stood at Semna and other places for the last four thousand years. Blocks 1½ inch cube sawn from old bricks (of Ptolemaic date) at Philæ which I tested only crushed with an average load of 178 lbs. per square inch.

Though all possessing the common properties mentioned above, different samples of the Nile mud must be expected to vary very

much in fineness and in the amount of organic matter they contain. As a type, I take a sample of the mud used for making bricks at the Reservoir works. Its plasticity when moist makes one think of clay, but a microscopic test shows it in reality to be a very fine sand or rock-flour with quartz and felspar in minute angular grains as its chief constituents. The grains do not as a rule exceed 0.1 m.m. in diameter; but what strikes one at once in comparing a mud and a sand is the absence of sizing. With the river-sand it is quite exceptional to find in the same slide grains more than twice as big, or less than half as big, as the average. But when one examines a slide of mud, one sees every gradation, from one-tenth of a millimetre to the finest particle visible with the highest powers (Plate III., Fig. 3), the smaller particles being frequently adherent to the larger ones. Herein lies, I think, the cause of the plasticity and toughness. It is a matter of sizing. It would seem that running water fails to separate completely grains of very different sizes when once the grains of over one-tenth of a millimetre in diameter are removed. Of course, the water after depositing such a mixed sample still contains very finely divided matter in suspension, so that if allowed to stand again it will deposit a still finer mud; but the point is that the first sample will itself contain a certain proportion of particles of a fineness equal to that of the smallest particles of the second. One can easily see that when the smaller particles accompany the larger, they may fit themselves into the voids between the latter. Thus the surface for a given weight of material is increased, the voids are smaller, and eapillary action is stronger. Further, on drying, contacts are made at a vastly increased number of points, cohesion is increased, and there must be a certain amount of inter-locking of the grains.

This testimony of the microscope that Nile mud consists essentially of minute *chemically-unaltered* fragments of igneous rock is admirably borne out by the results of chemical analysis, the percentage of combined water being generally so small as to forbid the assumption of the presence of any considerable amount of kaolinic matter. This will be seen from the table below, which gives the results of a number of analyses by Hofmann.*

* "An Account of some recent Researches near Cairo undertaken with the view of throwing light upon the Geological History of the Alluvial Land of Egypt," by L. HORNER, Phil. Trans., 1855, Part 1, pp. 105–138; 188, Part 2, pp. 53–92.

Column A shows the composition of the suspended matter (after baking) collected from the Nile water of Bulaq early in October (? 1849) at a depth of 20 feet below the surface; column B shows the analysis of a fertilising mud deposited at Damanhur by the flood of 1849; while in column C is given the mean of five analyses of "blackish brown earths which when moistened knead into plastic clays" taken from the Delta deposits at depths of 2 to 6 metres from the surface:—

	A.	B.	C.
SiO_2	53·04	56·86	55·40
Fe_2O_3	18·43	13·19	21·57
Al_2O_3	8·76	12·11	11·90
$CaCO_3$	4·19	3·12	3·81
$CaSO_4$	0·75	0·38	0·17
CaO	2·25	3·53	1·60
MgO	0·66	2·73	0·51
K_2O	0·69	0·90	0·29
Na_2O	2·16	0·89	0·20
NaCl	0·04	...	...
KCl	...	0·57	...
SO_3	...	...	0·09
Organic matter	9·03	5·53	4·46
Loss	...	0·19	...
	100·00	100·00	100·00

The recent analysis of 6 samples of cultivated soils from various parts of the Delta, at the Giza Agricultural College,* gave as a mean result:—

SiO_2 and insoluble	59·54
Fe_2O_3	9·66
Al_2O_3	13·08
Mn_2O_3	0·19
MgO	2·53
CaO	4·09
K_2O	1·06
Na_2O	1·17
Cl	0·56
SO_3	0·24
P_2O_5	0·29
CO_2	1·45
Volatile matter	6·07
	99·93

* Foaden and Mackenzie, "Journal of the Khedivial Agricultural Soc.," 1899, p. 138.

All these analyses tell the same tale. Even if what is quoted as organic and volatile matter really includes some water of combination, there cannot be any considerable proportion of hydrated silicates such as kaolin present, and we must infer that the alumina and part of the iron, lime and magnesia are present chiefly as anhydrous silicates such as felspar or hornblende, *i.e.* as original rock minerals.* The alkalies are probably also in great part present as felspar. The phosphoric acid has its origin in the apatite which is an almost constant accessory mineral in the igneous rocks of the south, and being in minute crystals it is likely to be found in greater relative abundance in the finer slimes than in the more sandy deposits.†

Thus, although we may speak of Nile mud as clay in an agricultural sense of the term,‡ thereby referring to its plasticity when wetted, the material really contains but a small proportion of the hydrated alumina silicates which are classed as clays by the mineralogist.

As we penetrate the superficial layer of mud and descend to the deeper alluvial deposits, we gradually pass into coarser materials, and usually reach clean river-sand at a depth of 5 to 10 metres.§ Thus, Horner || found some of these deeper deposits yielded the following results on analysis :—

	A.	B.	C.	D.
SiO_2	71·76	85·31	83·21	96·93
Fe_2O_3	7·81	5·98	6·01	2·05
Al_2O_3	10·40	2·76	4·09	1·02
$CaCO_3$	6·77	3·64	4·72	trace
MgO	0·76	...	...	...
Organic matter	2·50	2·31	1·97	...

* What has been mentioned above regarding the Nile mud is now becoming generally known to be the case with other soils. See DELAYE and LAGATU, "On the Constitution of Arable Earth", Comptes Rendus, Paris, Dec. 1904.

† It may be worth while to mention here that since most of the igneous rocks of the district contain titanium minerals in perceptible quantity, titanic oxide may find a place in future analyses of the Nile silt. In the older analyses the titanium is probably partly included with the insolubles (from ilmenite) and partly with the ferric oxide (from titanates).

‡ Clays are now frequently defined in agriculture with reference to their physical properties, without regard to composition; see, for instance, HALL, "The Soil," 1903, p. 34.

§ JUDD, "Proc. R. S.," Vol. 61, p. 34. I found a similar passage in the course of excavations for underpinning the Philæ temples in 1902.

|| *Op. cit.*

Of these, A is described as a grey sand from the apex of the Delta at a depth of 5 metres; it also shows a considerable increase of SiO_2 as compared with the mud. B and C show a still further increase of silica, while D is nearly pure siliceous sand from a depth of 20.4 metres. The reason for the high silica-percentage in the coarser material is, of course, the greater resisting power of quartz, as compared with felspar, in the grinding action to which the disintegrated rock material is subjected by the river.

Modern deposits other than from the Nile.—The floors of the gorges opening from the eastern hills into the Aswan-Shellal valley, especially near their mouths, are strewn with *igneous blocks;* these stones generally show only an imperfect rounding, and are evidently brought down by the short-lived mountain streams which occupy the gorges after the occasional heavy rains. The original breaking-up of the rock masses is largely brought about by expansion and contraction under the great diurnal range of temperature, aided by the joints due to crushing and faulting.

To the occasional rains must also be attributed the distribution of the *coarse granitic sand* which occupies a large portion of the old Nile course between Aswan and Shellal. The origin of this sand from the dry disintegration (without decomposition) of the acid granites is mentioned further on (p. 112). The effect of the rain is to wash it down from the hillsides and deposit it in more or less nearly horizontal layers on the valley floor. The process is one of extreme slowness, but in the course of centuries no insignificant thickness has accumulated. These deposits have furnished the chief source of supply of sand for mortar for the reservoir works, a purpose for which the sand is well fitted by reason of its sharpness and coarseness, as well as by the fresh state of the minerals (chiefly quartz and felspar) composing it. The material contains, however, a small proportion of soluble salts, which cause an efflorescence on the mortar made from it. A sample which was analysed contained 0.16 per cent. of soluble matter, of which the following constituents were determined:—

Sodium chloride............	0.03	per cent
,, sulphate	0.04	,,
Calcium carbonate..........	0.06	,,

There was also a small amount of nitrate, which was not, however, quantitatively determined. Another sample showed the main portion

of the salt present to be sodium carbonate. The presence of these salts is doubtless due to a small amount of chemical action of air and water on the felspar. As there is very little drainage from the sand accumulations, and very rapid evaporation, the soluble matters have been accumulating in the deposits for centuries; they may be expected to occur in very different proportions in different parts of the deposits.

The coarse *débris* of granite and gneiss brought down the khors and gullies by the occasional torrents resulting from storms, is occasionally found to be cemented into a *breccia* by siliceous matter; this cementing substance is harder than the granite itself, and appears to be the result of siliceous solutions trickling through the loosely piled mass of broken material. A good instance is to be seen in the gorge mentioned on page 41. If this gorge be followed up, one comes to a high ledge which forms a waterfall after rains. Part of the ledge is virgin rock, but there are also some transported blocks wedged into the mass, and these show the siliceous cementing very clearly. Numerous other cases can be seen on the road which leads into Khor Abajaj, mentioned on p. 40.

II.—The Nubian Sandstones and Clays, and their Relations to the Underlying Rocks.

These sedimentary strata consist of irregular alternations of white to brown sandstone with clays of prevailing grey colour, overlying the granite and other igneous rocks in beds everywhere practically horizontal. In the Cataract district they occur in greatest thickness to the north of Elephantine, where they form almost the entire face of the escarpments which limit the valley on either side. At Jebel Qubet el Hawa, the prominent hill on the west bank opposite Aswan, they attain a thickness of nearly a hundred metres, the clays here occupying about half the total height. On the east, where the sandstones predominate, this thickness is exceeded by about 20 metres. The sandstones and clays can be traced all along the west bank southwards, at an increasingly higher level, to near the south end of El Hesa island, where they retreat from the river owing to the height there reached by the igneous boss. On the east of the river, they cover the greater part of the plateau between the Nile and the railway,

while east of the latter patches of sandstone occur at numerous points. There is only one occurrence of sandstone on the cataract islands, and that is in the conspicuous flat-topped hill near the centre of Awad.

The *sandstone*, though of a brown appearance *in situ* in consequence of superficial oxidation of the small amount of iron contained in it, is generally nearly white in colour when broken. It is a soft rock when quarried, of a rather fine grain, and hardens under water; the cementing material is apparently a calcareous clay. It has been quarried to a considerable extent lately on the west bank for the purpose of pitching the sides of the navigation channel. Its specific gravity is about 1.85 to 1.95, and its resistance to crushing varies from 112 to 264 kilogrammes per square centimetre. It absorbs from 9.9 to 11.2 per cent. of water.*

Locally, the sandstone is subject to considerable variations. On the top of the western plateau it frequently contains oxides of iron and manganese in considerable amounts, rendering it of a black colour. Near the monastery of St. Simeon the sandstones and clays contain beds of ochreous matter and of earthy oolitic ironstone, which have the appearance of having been once worked. Hawkshaw found in the sandstone occasional crystals of barytes, but these are by no means common at the Cataract, though they are abundant in the corresponding sandstones of Baharia Oasis. In other places the usual somewhat fine grain gives place to a coarse grit, while at other points, again, it passes into a conglomerate. A large area of the plateau north-east of the dam is covered by pink quartz pebbles derived from the disintegration of conglomerate-beds in the sandstone. The base of the series is almost constantly a thin conglomerate-bed. This can be well seen by ferrying across to Jebel Qubet el Hawa; at the base of this hill the granite surface nearly coincides with the water-line of the Nile, and by going a little to the north, the conglomerate can be seen at the water's edge.

The *clays* are frequently finely laminated, grey and greenish in colour. In the neighbourhood of Aswan (south-east of the town) the beds have been largely excavated, probably to serve as manure on the lands; the practice does not appear to be continued in this

* Willcocks, "Egyptian Irrigation," 2nd Edition, p. 456. The strength of the stone increases rapidly with increase of density, hence in selecting samples for building purposes a high specific gravity should be sought for.

locality at the present day, though common a little further up the river. The Nubian clays generally contain a small percentage of alkaline nitrates, to which they owe their manurial value.*

As to the *age of these beds*, an upper limit is fixed by their stratigraphical position below limestones of undoubted Upper Cretaceous age; this position is well exhibited both in the Nile Valley (near Edfu) and in the Great Oasis. The inferior limit has till recently been less certain, for no sedimentary rocks of greater age exist in the immediate neighbourhood, and it is only within the last few years that any fossils other than silicified wood (an uncertain guide) have been found in the beds themselves. The age of the Nubian sandstone has in consequence been a frequent subject of controversy. Though it is certain that some similar sandstones in Sinai are Carboniferous,† it is equally certain that those of the Oases nearer Nubia itself are Cretaceous.‡ It is now proved that the sandstone of the Cataract district is also Cretaceous, the writer having been fortunate enough to obtain two specimens of *Inoceramus Cripsi* § from the sandstone beds close to the west end of the reservoir dam.

There remains the question as to the *relation between the sandstones and the igneous rocks*. Though it has been occasionally stated that the igneous rocks have intruded the sandstone || at various points, no evidence of such intrusion has been found either at the Cataract or in the country between it and Korosko, of which a very minute examination was made by the Geological Survey in 1899. Rather is the evidence very strong to prove that the igneous rocks are of much greater age. In the Cataract district there is no lack of exposures of the junction between the two rocks; a dozen places will easily be found suitable for observation along the road from Aswan to Philæ; but all these exposures tell the same tale. The top portion of the granite is broken down and weathered into a kaolinic mass; on this

* For an account of the use of clays (known as *tafla* or *marog*) as manures, see FOADEN, "Journal of the Khedivial Agricultural Soc.," 1903, p. 8.

† TATE, "Q. J. G. S.," 1871 pp. 404–406; SALTER, "Q. J. G. S.," 1868, p. 509; these conclusions have been confirmed by the finding of other Carboniferous fossils by the Geological Survey in 1899.

‡ v. ZITTEL, "Geologie der libyschen Wüste," Cassel, 1883; see also the published reports on the Oases, by the Geological Survey of Egypt.

§ Determination by DR. BLANCKENHORN.

|| ADAMS, "Q. J. G. S." 1864, pp. 6-19; FLOYER, *ibid.* 1892, pp. 576–582; also JOHNSON and RICHMOND, *ibid.* 1892, pp. 481–484.

come the sandstone beds, the lower ones almost invariably pebbly, ndicating that the granite was weathered prior to its covering up by the sandstone, and that shallow-water conditions accompanied the first sedimentation. This is shown in Fig. 3, which represents the section of the hillside at the east end of the dam.

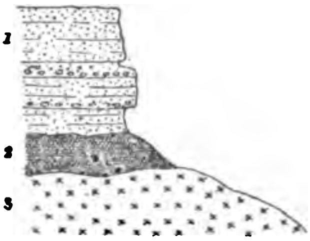


FIG. 3.—Junction of Nubian sandstone and granite, east end of reservoir dam. 1, Sandstone with conglomerate-bands; 2, Broken-down granite, a kaolinic mass with quartz-grains; 3. Granite.

Again, apart from the differences of level of the base of the sandstone produced by faulting, the surface of the granite boss is somewhat irregular; but the sandstone beds are everywhere practically horizontal. The higher igneous masses must have stood up as islands in the water which deposited the sandstone. Lastly, if the sandstone were older than the granite rocks, where are the evidences of contact-metamorphism, and how comes it that the sandstone shows no evidence of the action of those immense forces which have crushed the igneous rocks and faulted them into such a jumble as was exposed, for instance, in the excavation for the dam foundations? With the evidences before us, there can only be one possible rational deduction. The igneous and metamorphic rocks of the Cataract are of far greater antiquity than the sandstone which overlies them. Dawson,* basing his opinion on petrographical considerations, correlates them with the Archæan rocks of North America; whether the interval between the two deposits was really so great as this would indicate may well remain doubtful, but that an interval there was, and that a geologically long one, seems proved beyond all question.

III.—The Igneous and Metamorphic Rocks.

The igneous and metamorphic rocks of the Cataract district admit of classification as follows:—†

PLUTONIC ROCKS.

Granite.—Of this there are two well-defined types, readily distinguished by their difference of grain. They may be called the

* Geol. Mag. 1884, pp. 439-442.

† The system of classification employed is that of ROSENBUSCH, "Elemente der Gesteinslehre," Stuttgart, 1898.

coarse-grained red granite and the *fine-grained red granite* respectively.

Local variations of the coarse-grained rock into *hornblende granite* and *quartz syenite* are very common.

Syenite.—In this rock there are also considerable variations, but they are not as a rule sharply marked off from each other.

Diorite.—Much less abundant than the preceding rocks.

All the above rocks show in places modifications of structure in consequence of crushing. They also form, in addition to the large eruptive masses, dykes and veins.*

DYKE ROCKS.

Granite-porphyry series.	Aplitic series.
Quartz-felsite.	Aplite.
Syenite-porphyry.	Pegmatite.
Enstatite-porphyrite.	

VOLCANIC ROCKS.

Mica diabase.
Basalt (occurs here only in dykes).

METAMORPHIC ROCKS.

Gneiss.
Mica-schist.
Hornblende schist.

PLUTONIC ROCKS.

The coarse-grained red granite.—The coarse-grained red granite is at once the most abundant and best known of the igneous deposits of the Cataract. Its well-marked red colour (*see* Plate IV., Fig. 1) is due to the presence of large porphyritic red crystals of orthoclase and to smaller granules of the same mineral scattered through the mass. The large orthoclase crystals show a marked tendency to idiomorphic forms, and are frequently as much as 3 centimetres in length; they often show twinning on the Carlsbad type, the two halves of the crystals exhibiting difference of lustre when the speci-

* The mere fact of a rock occurring as a dyke does not make the rock a "dyke-rock" in the system of classification, See ROSENBUSCH, *op.-cit.*, p. 191.

men is turned about in the hand. In general, the red orthoclase forms about five-eighths of the entire rock. The remaining constituents are white oligoclase, always in small amount; quartz, fairly abundant; and black minerals, viz., biotite (easily recognised by its lustrous flakes), and hornblende. The hornblende is extremely variable in amount. It is sometimes altogether absent, but in the typical specimen it is always present in small quantity, and the rock may be correctly styled a hornblende-granite. Its specific gravity is 2.64.

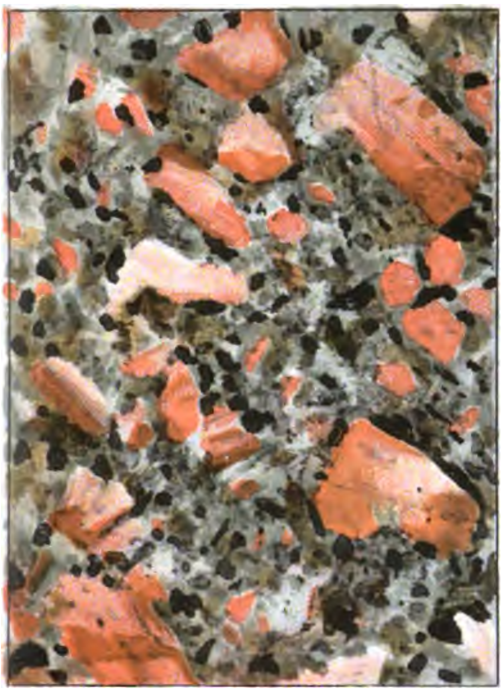
Under the microscope (Plate VI., Fig. 1) the greater portion of the rock is seen to consist of clear orthoclase, the smaller crystals seldom showing any approximation to idiomorphism; Carlsbad twins are extremely common. Oligoclase, easily recognised by its repeated twinning and low extinction angles in sections approximately perpendicular to the brachypinacoid, is far less abundant, being generally not present in greater amount than one-tenth of the orthoclase. Clear quartz, in allotriomorphic forms, occupies about one-eighth to one-sixth of a typical slide. The biotite is of a brown colour, in strongly pleochroic ragged-edged plates. The hornblende is always allotriomorphic, of green colour, strongly pleochroic. Apatite, in long minute prisms, is constantly present enclosed in the other minerals, but in small amount; and magnetite, usually as irregular grains but occasionally in idiomorphic forms, is also a constant but sparing constituent.

The principal primary variation in the rock is that due to the greater or less amount of hornblende. Where this constituent is developed in more than ordinary abundance, the quartz and biotite are present in less amount, the percentage of felspar remaining about constant. Very rarely crystals of sphene are found intergrown with the hornblende (Plate VI., Fig. 2, B).

The secondary variations revealed by the microscopic examination are of extreme interest. Kaolinisation of the felspars in slightly weathered specimens is of course frequent. But the freshest specimens show frequently strong evidence of dynamic action. A large portion of the granite mass can be seen in the field to have undergone crushing, giving it more or less of a gneissose appearance. Slides cut from these portions, even where the hand specimen exhibits no trace of alteration, reveal (Plate VI., Fig. 2, A) the almost entire change

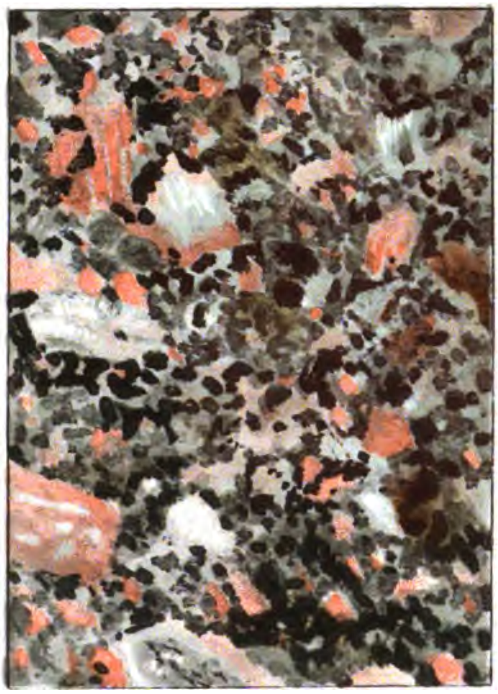
NATURAL SIZE.

1



Coarse-grained red Granite.

2

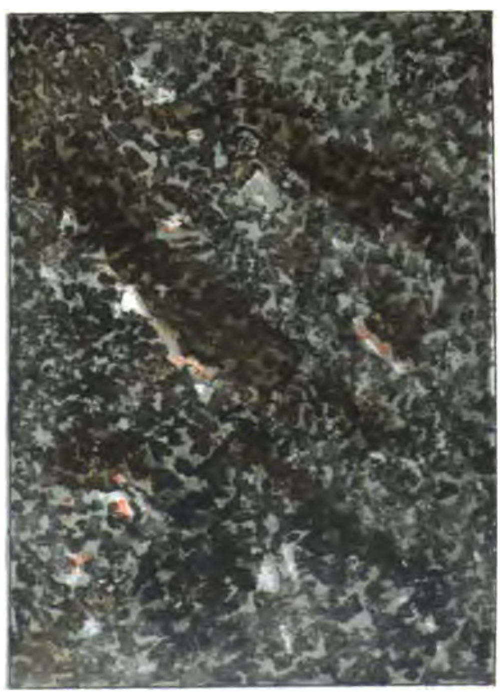


Hornblende-granite.

3

Quartz-mica-Syenite, with porphyritic Felspars.

4



Syenite.

Bemrose, Collo.,

NATURAL SIZE.

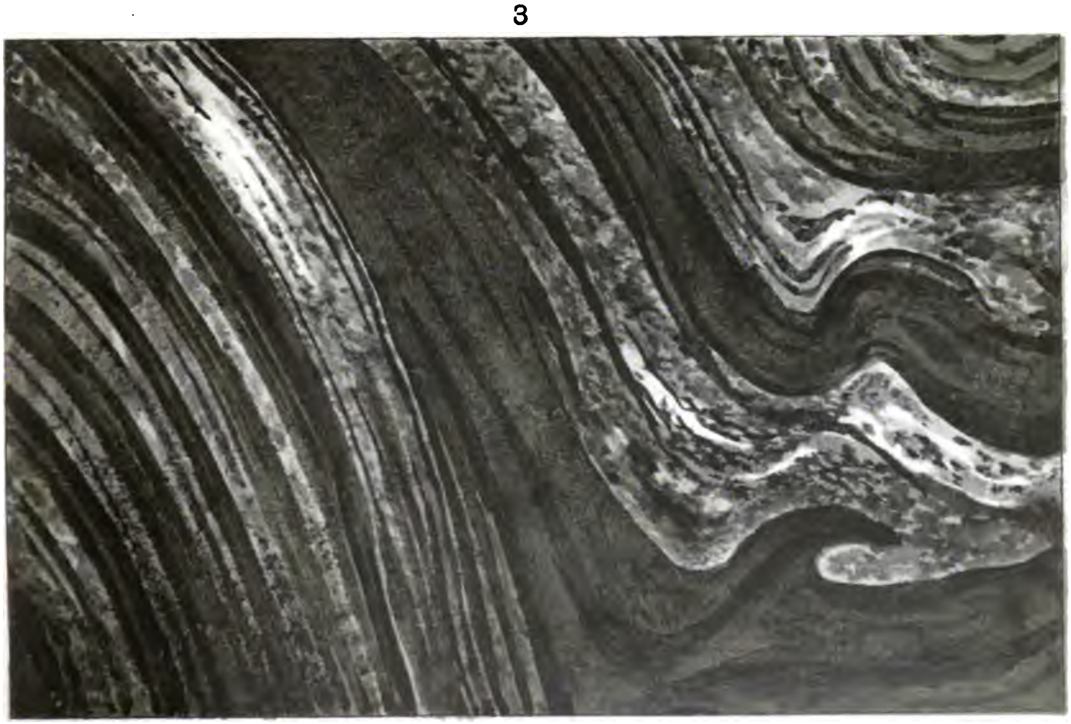
1

Fine-grained red Granite.

2

Diorite.

3



Contorted Hornblende-schist with quartzose bands.

Bemrose, Collo., Derby, Eng.

of orthoclase into microcline, while around the large crystals is a "mortar" of small granules resulting from the attrition consequent on the sliding produced by the crushing-action. Cracking of the large crystals and undulose extinction due to their state of strain are also frequently seen in these slides.

Analyses of the rock by Delesse,* Scheerer,† and Wigner ‡ gave the following compositions :—

Delesse, 1851		Scheerer, 1866		Wigner, 1878	
Silica	70·25	SiO_2	69·95	SiO_2	68·18
Alumina	16·00	TiO_2	0·95	Al_2O_3	16·20
Ferric Oxide	2·50	Al_2O_3	13·32	Fe_2O_3	4·10
Lime	1·60	FeO	4·90	Mn_2O_3	traces
Alkalies and Magnesia (by loss)	9·00	MgO	0·66	CaO	1·75
Loss by incineration.	0·65	CaO	1·79	MgO	0·48
		Na_2O	3·31	Na_2O	2·88
		K_2O	3·47	K_2O	6·48
		H_2O	1·27		
	100·00		99·62		100·07

Wigner also analysed the felspar and mica separately, with the following results :—

	Felspar	Mica
$Si O_2$	63·38	46·16
$Al_2 O_3$ / $Fe_2 O_3$	22·25	31·18 / 7·30
Ca O	1·09	....
Mg O	0·45	6·77
Na_2 O	1·84	0·92
K_2 O	10·66	5·24
	99·67	97·57

The coarse-grained red granite forms the greater part of the igneous hill-masses between Aswan and Shellal, underlying the great sandstone plateau between the road and the railway. East of the railway

* Q. J. G. S., 1851, pp. 9–13. The specimen was from a piece of the rock in the Louvre.
† Quoted in Roth's "Beiträge zur Petrographie," 1869, p. XIV i.
‡ H. H. Gorringe, "Egyptian Obelisks." London, 1885, p. 161.

line it is not met with till a point almost due east of the reservoir-dam is reached, and then it is found in a highly crushed condition, being practically a gneiss. On most of the Cataract islands it forms an important feature. It is also exposed below the sandstone at many places along the west bank.

Where normally developed, as, for instance, west of the Aswan-Shellal railway line, the coarse-grained granite exhibits the form of piled-up rounded masses, due to its weathering into spheroidal forms, as shown in Fig. 4. The surface is usually of a grey or nearly black colour where long exposed, and occasionally separation of thin spheroidal shells can be seen; but as a rule the weathered layer is extremely thin, so that rounded blocks furnish good quarrying material, the whole interior being perfectly sound fresh rock. Such masses are in fact less liable to fissures than the massive rock below, as their separation has itself gone on wherever a plane of weakness existed in the parent mass. It is chiefly on these large rounded blocks that the hieroglyphic inscriptions so abundant on the road between Aswan and Shellal are found.

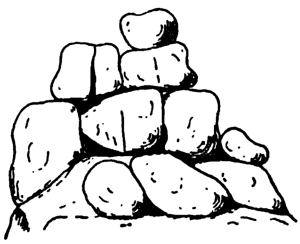


Fig. 4.—Typical weathered form of normal Aswan granite.

The appearance in the field of the granite where much crushing has taken place is totally different. The mass now weathers into parallelopipedons, as shown in Fig. 5. This form of the rock can be well seen in the gorge east of the great bend in the railway line, where the crushed and gneissose rock has been washed out by a torrent.

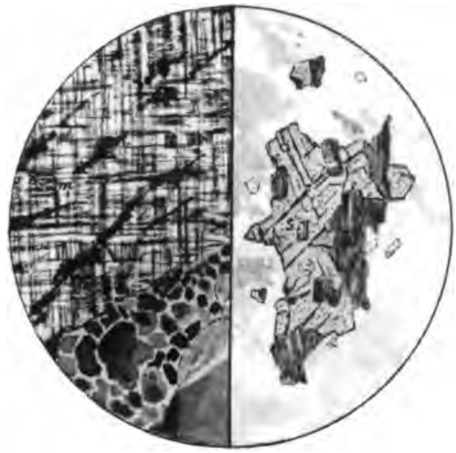
Fig. 5.—Weathering of crushed granite and gneiss.

Near the river, wherever the granite has been long exposed to the action of the river-water, its surface has acquired a thin, hard, black coating with a blacklead-like lustre. The nature of this film has recently been studied by Lucas,* who finds it to contain the oxides

* "The Blackened Rocks of the Nile Cataracts," Cairo, 1905.

1

A 2 B



3

4

1. COARSE-GRAINED RED GRANITE, ASWAN DAM, x 10. *q*, quartz; *o*, orthoclase; *b*, biotite; *h*, hornblende; *m*, magnetite; *a*, apatite.

2. A. Microcline (*m*) and crushed quartz (*q*) in COARSE-GRAINED GRANITE, SHELLAL, as seen between crossed Nicols, x 20.

B. Intergrowth of sphene (*s*) and hornblende (*h*) in COARSE-GRAINED GRANITE FROM THE NAVIGATION CANAL, x 25. The intergrown crystal is surrounded by quartz and felspar.

3. SYENITE, JEBELTOGOK, x 20. *o*, orthoclase; *ol*, oligoclase; *g*, accessory quartz; *h*, hornblende; *b*, biotite; *a*, apatite; *m*, magnetite; *sp*, sphene.

4. QUARTZ-MICA-SYENITE, SOUTH END OF NAVIGATION CANAL, x 20. *o*, orthoclase; *h*, hornblende; *b*, biotite, altering to chlorite (*c*); *q*, quartz; *m*, magnetite; *a*, apatite; *sp*, sphene. (The rock contains large porphyritic felspar crystals (orthoclase), in addition to the allotriomorphic forms seen in this slide, and there is also a small proportion of oligoclase present.)

Bemrose, Collo., Derby, Eng.

of iron and manganese, also lime, magnesia, potash, silica, and sulphuric and phosphoric acids. Its origin, however, is still uncertain. It may be either the result of a rearrangement of the molecules of the superficial portion of the rock under the influence of the water,* or a direct deposit from the Nile water itself. Either source would be in agreement with the chemical evidence, since both rock and water contain the elements present in the film; but Lucas inclines to the former hypothesis.

Pot-holes are very abundant in the low-lying rocks of Thirmosia and other Cataract islands; holes 20 or 30 centimetres in diameter and as much as a metre deep are frequently seen at low Nile, the stones and sand which bored them by their gyration lying still in the bottoms of the holes. So frequent are these holes in some places that one has to pick one's way carefully to avoid setting foot into them.†

Owing to almost total absence of the ordinary weathering influences (rain and frost) in the district, it is but seldom that extensive kaolinisation of the felspar and consequent disintegration of the rock, so commonly seen in other granite areas, is met with at the Cataract. But in the excavations for the dam foundation and navigation canal, below the level of high Nile, such weathering was frequently exposed. On the sides of the navigation channel the rock was found to be almost completely decomposed to a depth of several metres below high Nile level, small kernels only of unaltered rock being left. Along the line of the dam the scouring action of the flood has naturally carried away the soft decomposition-products as fast as formed near the surface, but even here kaolinisation has gone on along the fissures to great depths, wherever water could percolate. When the west channel was laid dry for the preparation of the Nile dam foundation, a north and south fault was found to run nearly down its centre. At this fault greenish, chloritic slickensides were very abundant; but at a few decimetres distance on either side the rock was distinctly the coarse-grained granite, highly kaolinised and stained green, while on

* This is suggested as a possible explanation from the fact that the formation of a brown skin on syenite porphyry of the Semna cataract has been shown to be accompanied by a molecular migration. See "The Semna Cataract." Q. J. G. S., 1903, p. 71.

† Prof. Brunhes has recently made a careful study of the pot-holes on the islands near Elephantine. See "Mem. Soc. Fribourgeoise des Sciences Naturelles," Fribourg (Suisse), 1902 pp. 154–224.

following up away from the fault the rock was seen to pass into the ordinary form. There can be no doubt that a fissure originally existed here, along which, aided by percolating water, decomposition went on; and that at a later date a great thrust took place resulting in the fault and its slickensides. Similar, though less sharply defined, faults cross the dam-axis in a north direction at numerous other places, as will be evident from an inspection of the section on p. 87.

Passing to the economic consideration of the Aswan granite, we may briefly note that the Aswan quarries were worked in very ancient times, and were in fact the scene of the earliest quarrying operations of which we have any historical record. From the fourth dynasty (more than five thousand years ago) onward to Ptolemaic times, the Aswan quarries were worked at intervals to furnish stone for the more ornamental portions of temples and other structures; the quarrying industry probably reached its maximum in the eighteenth dynasty, when Senmut, the architect employed by Queen Hatshepsut, completed the great obelisk of Karnak, over a hundred feet high, in seven months. Senmut * was a great organiser of labour, and to him are doubtless due the quarry-roads which still exist. From about the dawn of the Christian era to our own day, the quarries have remained unnoticed, the easily obtainable limestone of Lower Egypt having been preferred to the more beautiful but costly granite. With the construction of the Nile reservoir in 1898 began a new epoch in the Aswan quarrying industry, a hard and heavy stone being necessary for this class of work, while the highly ornamental character of the granite, its proximity to the site of the dam, the absence of weathered over-burden, and its comparatively (for a granite) easy working, have been additional points in favour of its adoption. The whole of the ashlar facing and much of the interior rubble of the dam are of this rock.

The principal ancient quarries were in two localities, one situated about a kilometre south of Aswan, and the other on the east side of the plateau, nearly in the line of an eastward prolongation of the dam-axis; but besides these, other smaller quarries existed on Elephantine and Sehel, and at a few other points. In their selection of these sites the Egyptians showed good judgment; for they are pre-

* For an account of this great architect and his works, see NAVILLE "Deir el Bahari," (Egypt Exploration Fund Memoirs), also PETRIE, "History of Egypt," Vol. II, 1899, p. 88.

cisely the places where the soundest rock and best transport conditions are to be found. The ancient paved quarry roads, with their earth embankments for facilitating descent or passage across wadis, can still be traced, while in the quarries themselves are various unfinished pieces of sculpture and half-separated blocks which inform us as to the method used in the extraction of the stone. That method was to cut a series of rectangular holes along the proposed line of fracture, and then to drive in wooden wedges, which when wetted expanded and broke off the block. Numerous lines of such wedge-holes, as well as isolated holes probably the practice work of prentice hands, can still be seen. As much sculpture as possible was done in the quarry, so as to diminish the weight to be transported. Transport to the river was probably accomplished by rollers and ropes, worked by a large number of men, and on the river itself by rafts.*

At the present time the quarrying is accomplished partly by blasting with gelignite (for the breaking down of large masses) and partly by splitting with steel wedges. Though exhibiting to the ordinary eye perfect homogeneity, the granite has certain directions in which it can be split with greater readiness than in others, and the special granite quarrymen are very skilful in taking advantage of this property. From the highly ornamental nature of the rock and its proximity to the river, it would appear that it is capable of furnishing at not too great a cost a valuable addition to the building-stones of Egypt; it is to be hoped, now that the quarrying operations for the reservoir have re-opened the industry, that the exploitation of the stone will be continued for the ornamentation of the more important buildings to be subsequently erected in Cairo and elsewhere. It offers an ideal material, not only for columns and pilasters, but also for street kerbs, for paving setts, and for the lower courses of buildings, which if of limestone soon decay near the ground level; while the refuse chips of the quarries would furnish a very good road metal, equal if not superior to the basalt now used in Cairo.

The strength of the granite to resist crushing is of little practical importance, but it may be mentioned that Sir W. Willcocks † gives

* On the ancient quarrying of granite at Aswan, see De Morgan, "Catalogue des Monuments. etc.," 1894, also the paper by de Rozière, printed as Appendix to the first volume of the "Description de l'Égypte".

† "Egyptian Irrigation," 2nd Edition, p. 457.

its ultimate resistance as 1,307 to 1,530 kilogrammes per square centimetre. How great a margin this leaves in practice may be gathered from the fact that the greatest pressure on the foundation of the Aswan dam is computed at 5 kilogrammes per square centimetre. The stone is practically non-absorbent in water. No information has been obtained by the author as to its transverse strength, but built-in lintels of an ordinary size up to two metres span, if free from flaws, are perfectly safe, and are in fact used over the sluices of the reservoir dam.

The fine-grained red granite.—This rock differs from the preceding chiefly in being of a much finer grain. It is devoid of porphyritic crystals, and the individual mineral grains seldom attain to more than 3 or 4 millimetres in diameter (*see* Plate V., Fig. 1). Its red colour is more pronounced and uniform than that of the coarse-textured rock, partly on account of the difference of grain, but chiefly owing to a lower proportion of dark-coloured minerals being present. Under the microscope it shows a very similar appearance to the coarse-grained granite already described, except that there are no porphyritic felspars and all the minerals are purely allotriomorphic; hornblende is generally entirely absent, and the percentage of biotite is very small, the rock frequently approaching an aplite in mineralogical composition. Accessory apatite and magnetite are sparingly present.

Though less abundant than the coarse-grained rock, this fine-grained granite forms no insignificant portion of many of the hills, especially on Saluja, Awad, and El Hesa islands, and on the mainland between the reservoir dam and Mesitot. It is also prominent on both banks

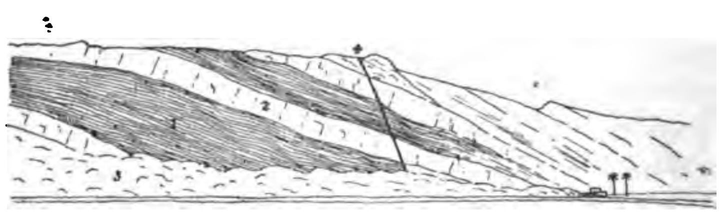


Fig. 6.—Sketch of the rocks on the west bank opposite Ajarma. 1, Soft highly decomposed micaceous schists and gneisses. 2, Hard fine-grained red gneissose granite. 3, Debris of schists, gneisses and granite at foot of slope. 4, Porphyrite dyke.

of the river about the latitude of El Hesa, where it forms thick bands in the decomposed mica schists and gneisses (Fig. 6). In the field it

generally forms less rounded masses than the preceding rock; it is frequently highly crushed and passes into a gneiss. Its highly acid character renders it very resistant to weathering influences. Where it has yielded to these it shows the same features as the coarse-grained rock.

As regards the relative ages of the two granites, the evidence is somewhat conflicting, the two rocks being much mixed up and each sending off veins into the other, while the later dykes of porphyrite and basalt traverse the two rocks together; but as a general rule the fine-grained rock shows distinctly more signs of crushing than the coarser one, and is probably the older of the two.

As a building-stone, the fine-grained granite is generally somewhat harder to work than the coarse rock, while it is often crushed to such an extent that blocks of large size cannot well be quarried owing to closeness of the joint-planes. Partly on this account, and partly from considerations of appearance, the coarse-grained granite is naturally preferred to it for external work. In the dam the fine-grained rock was however very largely used for interior rubble. It is a hard and very durable stone.

Syenite.—In many parts of the Cataract district the coarse-grained granite passes by insensible gradations into a true syenite.* The quartz is seen in far less abundance, becoming a merely accessory constituent; the percentage of felspar is only slightly altered, and orthoclase is still the predominant mineral of this class; though oligoclase is seen in greater relative abundance than in the granite; and the large porphyritic orthoclase crystals, while still occasionally met with, are far less prominent, the rock thus taking on a more even texture. Biotite remains an important constituent, though less abundant than the hornblende; the latter is present in considerable amount, and gives the dark colour to the mass. The specific gravity of the rock rises from 2.65 in the normal granite to 2.84 in the true syenite. The progressive passage from granite to syenite as seen in hand specimens is exhibited in the illustrations on Plate IV.

* Though first applied to the principal Aswan rock by Pliny, the term syenite was used about 1788 by the Saxon geologist Werner as a name for a hornblende-orthoclase rock quarried in the neighbourhood of Dresden, and has since been adopted in petrography as a distinctive name for rocks of this composition. Thus in modern nomenclature the rock to which the name syenite was first given is called a granite (hornblende-granite in part); true syenite (in the modern acceptation of the term) does occur at Aswan associated with the granite, but is less common than the latter.

Under the microscope (*see* Plate VI., Figs. 3 and 4; and Plate VII., Fig. 1 and 2) quartz, orthoclase, and oligoclase show the same appearance as in the granite, but their proportions are altered, quartz being only an accessory constituent. The felspars frequently contain enormous numbers of minute prisms of apatite; and fairly large crystals of the same mineral, always in well defined idiomorphic forms, are scattered among the other minerals. Biotite of brown colour is frequent, in rather large brown flakes. Hornblende, which with the orthoclase gives its distinctive character to the rock, is very abundant in allotriomorphic forms, strongly pleochroic (green to olive); though occasionally found altering to chlorite, it is generally very fresh, with well marked cleavage. The extinction-angle $\mathfrak{c}$ — c averages about 18°. The biotite and hornblende are frequently intergrown. Sphene is constantly present in small quantity, sometimes in its characteristic wedge-shaped idiomorphic forms, but more usually in rounded grains. Ilmenite and magnetite are also present in considerable quantity in small opaque grains. Part at least of the sphene appears to be a secondary formation produced by alteration of ilmenite, for kernels of the latter mineral are found to occur in the former.

Where slight alteration of the rock has taken place, microscopic slides exhibit kaolinisation of the felspars, while the biotite is undergoing change to chlorite, frequently with separation of large flakes of iron oxides.

Syenitic variations are specially common in the granite masses round Jebeltogok and further south on the east side of the Aswan-Shellal road, as well as on many of the Cataract islands between Sehel and the reservoir dam. The intermediate stages between the granite and true syenite (hornblendic granite, quartz-mica syenite, and so on) are well seen at nearly all these places. In the field, the syenitic patches in the granite are readily distinguished from a distance by their darker colour. Syenite, consequent on its more basic nature, weathers more easily than granite, but it assumes the same forms.

The upper portion of a large mass of syenite cut through in the excavation of the navigation channel exhibited spheroidal weathering in a remarkable manner; decomposition had gone on in concentric shells, leaving kernels from a few centimetres up to a metre in diameter of sound rock, round which the decomposed (kaolinic and chloritic) material formed a pseudo-schistose mass. The rock itself

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1. SYENITE, NAVIGATION CANAL, x 35, or orthoclase, including numerous crystals of *a*, apatite; *h*, hornblende; *b*, biotite; *q*, accessory quartz; *m*, magnetite; *sp*, sphene.

2. FINE-GRAINED MICA-SYENITE, NORTH-EAST OF SHELLAL, x 40, or orthoclase (the rock contains also a little plagioclase); *b*, biotite, altering with separation of *l*, limonite; *h*, hornblende, much chloritised and intergrown with the biotite; *q*, accessory quartz; *a*, apatite.

3. DIORITE, NEAR MISHEK, x 20. The rock is almost entirely composed of labradorite, *l*, and hornblende, *h*. This slide shows also accessory sphene, *s*, resulting at least in part from alteration of ilmenite, *i*, kernels of which remain; there are also a few wisps of pale green mica, *m*.

4. FINE-GRAINED QUARTZ-FELSITE, DYKE SOUTH OF TENGAR, x 100. felspar, mostly orthoclase, in more or less idiomorphic crystals, much altered, especially at borders, and coloured by iron oxide even in thin section; *q*, quartz, with numerous acicular enclosures; *m*, mica, in minute flakes; *h*, haematite; *gr*, ground-mass, not sharply marked off from the decomposition-products of the felspars. The whole rock is strongly coloured by finely-disseminated ferric oxide.

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was free from schistose structure, but had the kernels not been left as evidence of what had gone on, the altered portion might easily have been mistaken for a contorted decomposed schist (Fig. 7).*

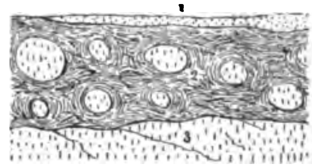

Fig. 7.—Weathering of syenite as seen in excavation of navigation channel. 1, Alluvium. 2, Zone of decomposing syenite with spheroidal kernels of unaltered rock, round which the decomposition products are arranged in concentric shells, giving rise to a pseudo-schistose appearance. 3, Unaltered syenite.

A very fine-grained variety of syenite, evidently of later age than the rocks just described, is found in dykes and thin sheets cutting the ordinary granite and syenite of the hills on the east side of the Aswan-Shellal road. In some places the broken-up sheets cap the hills over a considerable area. The rock is very conspicuous owing to its black colour, save where long exposed to weathering. It is extremely hard, ringing when struck, and somewhat resembles a basalt in appearance. Under the microscope, however, it is seen to be a holocrystalline rock, identical in mineral composition with the ordinary syenite of the district already described, the crystallisation being merely on a much smaller scale. The crystals of hornblende frequently show a smashed-up appearance, and the rock has evidently had some crushing. Owing to its occurring only in thin dykes and sheets and to its intractable nature under the hammer, this rock is of no economic importance.

Diorite.—Diorite is much more scarce at the Cataract than the plutonic rocks already described, being found only at a few points, and then nearly always passing into hornblende schist. The typical rock, where least altered by crushing, is a fairly coarse-grained aggregate (*see* Plate V., Fig. 2) of greenish-black hornblende and milk-white felspar, these two principal constituents being present in about equal amounts. The rock is hard and heavy, its specific gravity being 2.98.

Under the microscope (Plate VII., Fig. 3) the two minerals abovementioned, hornblende and felspar, are seen to be accompanied by a little accessory biotite, and by occasional granules and small idiomorphic crystals of sphene. The felspar is of course plagioclastic, in allotriomorphic forms, generally very fresh, the repeated twinning

* It is interesting to note that a similar phenomenon was noticed in the excavation in granite for the foundation of the Sheepstor embankment, in connection with the water supply of Plymouth, Proc. Inst. C. E., CXLVI, 1901, p. 15

being well seen; the maximum extinction angle observable in sections perpendicular to the brachypinacoid is 40°, so that the felspar is labradorite. In the more decomposed crystals of the felspar, calcite, epidote and kaolin appear as alteration-products. The hornblende is in green to olive-brown strongly pleochroic crystals, seldom showing any approximation to idiomorphism; the cleavages are well marked, and the maximum extinction angle $\mathfrak{c} - c$ is about 23°; occasionally the hornblende appears to be altered at the edges to epidote, which forms small irregular granules.

As above mentioned, diorite is seldom met with at the Cataract. It is, however, well seen underlying the sandstone east of the railway about the latitude of Sehel, also near Mishek and in small patches on Sehel and Aisanarti islands, forming irregular masses in the granites and syenites.

Both the larger masses and the dykes of diorite are frequently much crushed, passing almost invariably, when followed up, into hornblendic schists and gneiss. The masses break very irregularly owing to numerous cracks, and on this account, though a beautiful stone where not crushed, the rock is of little importance as a possible constructive material. Even where sound blocks can be extracted, the stone is still very difficult to work, breaking capriciously along lines other than the wedge lines. It has not been used on the reservoir works.

DYKE ROCKS.

The dyke rocks represented at the Cataract belong to the granite porphyry and aplitic series. No rocks of decidedly lamprophyric type have been met with, the darker dyke rocks being all apparently referable to the porphyrites, though their advanced state of alteration renders classification somewhat doubtful.

Granite-Porphyry series.

Quartz-felsite.—A great number of red to brown dykes of fine-grained rocks of felsitic appearance occur in the plutonic masses of the Cataract. Under the microscope these are found to be nearly all less acid in character than their appearance in the field would indicate, and they nearly all belong to the intermediate class of dyke rocks. Some of the dykes, however, *e.g.*, to the south of Tengar, may be classed as quartz-felsites, and are thus the dyke-representatives of granite. The

dykes are generally about a metre in width, and run fairly straight for considerable distances, with a south-westerly strike. The rock is a hard, extremely close-grained one, of reddish-brown colour; the colour causes the course of the dyke to be very clearly seen where not too much covered by granite debris. With the lens, tiny crystals of quartz and felspar can be detected here and there, but the bulk of the rock is too fine-grained for a lens to be of much service.

Under the microscope (Plate VII., Fig. 4) felspar is seen in idiomorphic crystals; it is mostly orthoclase, but is much altered, especially at the edges, and even the thinnest sections are coloured red by finely disseminated iron oxide. Quartz is not very abundant; it occurs in clear irregular grains among the felspars, and contains numerous fine acicular enclosures. In the ground-mass is much hæmatite and limonite, with occasional flakes of biotite. The ground mass is not sharply marked off from the decomposition products (kaolin, etc.) of the felspars, owing to the highly altered state of the rock, and the strong iron colouration renders the mass difficult of examination in transmitted light.

Syenite-porphyry.—A boss intruding into the granite on the west side of the railway about midway between Aswan and Shellal appears to be a highly altered syenite-porphyry. The rock, which is very hard and tough, is of a reddish-brown colour, the dark ground-mass being full of fine white rod-like felspar crystals, generally less than a millimetre in length.

Under the microscope (Plate VIII., Fig. 1) the rock is seen to be very nearly holocrystalline. Lath-shaped felspar crystals, chiefly orthoclase much decomposed in the centres, are very abundant; the decomposition-products and the borders of the crystals are coloured red by finely disseminated particles of iron oxide. Fairly plentiful remains of an altered ferro-magnesian mineral (biotite or hornblende) are seen in irregular flakes which now consist almost entirely of iron oxides; scattered among these main constituents is a little secondary quartz, and there appear to be traces here and there of an altered ground-mass.

From the boss there run off several dykes, striking generally east-north-east. Some brown felsite-like sheets seen in the granite on the west side of the hill-mass are probably also from this origin.

Porphyrite.—Near Tengar a compound dyke about a metre in width is found cutting the granite and schists of the hills

(Fig. 8). The darker of the two dyke rocks, which appears to be the younger from its less advanced state of alteration, may be classed as a porphyrite; it is of a chocolate-brown colour, very fine in grain, with green specks. The microscopic section (Plate VIII., Fig. 2) shows porphyritic plagioclase crystals, still clear in places, though mostly turbid and changed to kaolin and calcite in a mass of dark greenish-brown chloritic matter. The latter is clouded and full of opaque hæmatite particles, so that it is difficult to determine exactly what it is; it seems to be a decomposition-product of ferro-magnesian minerals (hornblende or biotite), but no trace of either of these minerals appears to exist unaltered. As in the rock just described, there appears to have been a small amount of ground-mass in the interstices between the larger crystals, but this cannot now be clearly distinguished from the alteration-products of the felspars.

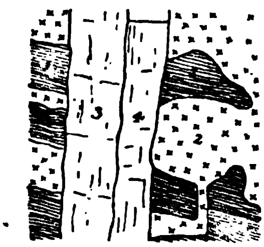

Fig. 8.—Sketch of two dykes filling a twice-opened fissure in granite and schists, Tengar. 1, Decomposed mica-schists. 2, Red granite intrusions. 3, Dyke of quartz-diorite-porphyrite, highly altered, 60 cm. wide. 4, Dyke of diorite-porphyrite, altered, 45 cm. wide.

The lighter coloured dyke which accompanies the above is a very compact, fine-grained rock of an Indian red colour. No crystals can be made out even with the lens. It is a highly altered quartz-diorite-porphyrite. The section reveals evidence of crushing in the undulose extinction of the quartz crystals. The felspar, which forms the bulk of the rock, is too decomposed for precise determination: it is in long lath-shaped forms, and doubtless plagioclase. The whole mass is impregnated with opaque particles of hæmatite and limonite, and no other original minerals than quartz and plagioclase can be with certainty made out, though there cannot be much doubt that much of the hæmatite results from decomposition of biotite or hornblende, or both, contained in a ground mass.

Enstatite-porphyrite.—The transverse channel connecting the two main branches of the river south of Sehel Island follows the line of a large compound dyke, which can be well seen at the east side of the channel. The dyke is about 10 metres in width, striking nearly due east and west, and cutting vertically through the granite. It is so highly crushed that the extraction of even a hand specimen of

Rocks of the Aswan Cataract.

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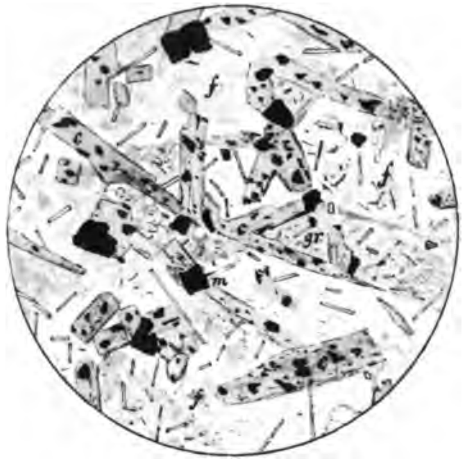

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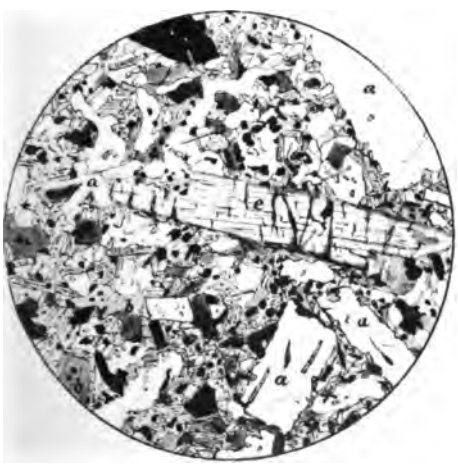

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1. ALTERED SYENITE-PORPHYRY, FROM A BOSS BETWEEN ASWAN AND SHELLAL, x 45. *f* felspar, mostly orthoclase, decomposed and stained by ferric oxide; *h*, *l*, haematite and limonite, resulting from decomposition of a ferro-magnesian mineral (hornblende or biotite) of which no trace now remains unaltered; ***gr***, interstial ground-mass, not abundant; *q*, secondary quartz.

2. ALTERED PORPHYRITE, FROM A DYKE NEAR TENGAR, x 85. *f* felspar (plagioclase), much decomposed to calcite and kaolin, and containing abundant needles of apatite; *c*, chlorite, with included small flakes of haematite, resulting from the decomposition of a ferro-magnesian silicate, probably hornblende, of which however no unaltered trace remains; *m*, magnetite; *gr*, ground-mass, not clearly distinguishable from the decomposition-products of the felspars, coloured by finely-disseminated ferric oxide and containing much calcite.

3. ENSTATITE-PORPHYRITE, FROM THE DYKE SOUTH OF SEHEL ISLAND, x 50. Porphyritic crystals of enstatite (*e*) and andesine (*a*), in a holocrystalline ground-mass made up of biotite (*b*), enstatite, and andesine, with numerous scattered grains of magnetite.

4. MICA-DIABASE, FROM UNDER THE ASWAN DAM, x 35. *pl*, plagioclase (andesine); *a*, augite; ***b***, biotite, altering to chlorite with separation of iron oxide; *h*, hornblende; *ap*, apatite.

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the ordinary size is a matter of difficulty, the mass breaking easily into prismatic forms bounded by crush-planes. The shattered nature of the dyke renders it incapable of offering much resistance to erosion, and this accounts for the formation of the transverse channel.

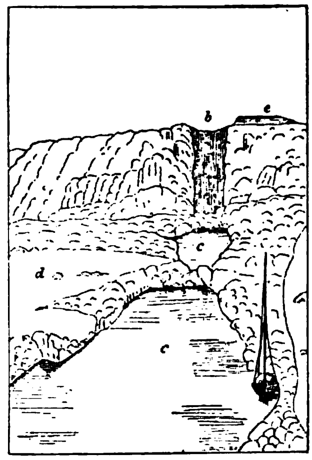

Fig. 9.—Sketch of compound porphyrite dyke in granite, south of Sehel Island, as seen from the west; *b*, dyke; *c*, narrow channel due to erosion along dyke; *d*, Mesitot Island, mud covering rocks; *e*, Nubian sandstone capping granite hills.

In the channel itself at low water numerous islets of the dyke rock can be seen, and the dyke doubtless extends to the west bank near the village called Negar el Hagar; here, however, the accumulation of blown sand has covered up the rocks. Dykes in a parallel direction can be traced further east, to the place where the sandstone caps the granite. Here the numerous parallel dykes run out from a considerable mass of a rock similar to themselves, probably a neck. Beyond the sandstone, still further east, dykes of the same system can be seen in the granite.

The central part of the dyke as exposed on the east bank of the river near Mesitot is a nearly black, heavy, close-textured rock, in which, with the aid of a lens, small crystals of plagioclase and tiny rods of pyroxene can be made out. The edges of the dyke, owing to more rapid cooling, are much finer-grained, and have more the appearance of basalt.

Under the microscope (Plate VIII., Fig. 3) plagioclase (andesine) is seen to be abundant in clear crystals, approximating to idiomorphic forms; enstatite or bronzite, of a very pale brown colour, is constantly but less abundantly seen in long fibrous-looking forms. These two minerals are porphyritic, in a holocrystalline ground-mass with numerous small flakes of biotite and perhaps granules of hornblende (greenish). There is much scattered magnetite in tiny granules.

Aplitic Series.

Aplite.—Though very frequent in the form of dykes in the granite and gneiss of Lower Nubia, aplite is very seldom met with in the immediate vicinity of the Cataract. Dykes of aplite up to three

metres' width were, however, cut through at a few points both in the dam-foundation and in the navigation channel. The rock is a fine-grained granular one, of great hardness ; it is very rich in quartz, of a pale bluish to pink colour in the mass, and breaks with a sub-conchoidal fracture. Its specific gravity is 2.59 to 2.61. In the field examination it would be easily taken for quartzite, but microscopic sections show it to consist of a fine mosaic of quartz and clear felspar (microcline and plagioclase), the latter frequently in nests with abundant quartz inclusions, and a few flakes here and there of brown biotite.

Pegmatite.—Pegmatite is the dyke rock most frequently met with at the Cataract. It is generally a very coarse-grained intergrowth of vitreous quartz and red orthoclase, the latter being the more abundant constituent. The specific gravity of the rock is 2.61. The individual crystals (which are of course allotriomorphic) frequently measure 5, and sometimes 10 centimetres across. Graphic structure is occasionally seen, but is decidedly uncommon. Sometimes quartz is almost absent, and we have dykes practically of orthoclase rock. In other cases quartz predominates, giving dykes of almost pure vitreous quartz. To the north of Aswan at the foot of the eastern scarp bounding the valley, and a little beyond the north limit of the general map of the Cataract (*see* the small additional map on Plate IX.), is a large mass

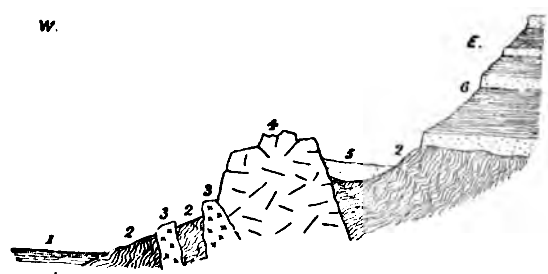

Fig. 10.—Section (from west to east) of the quartz mass north of Aswan. 1, Alluvium of the Nile. 2, Grey micaceous schists. 3, Pegmatite dykes. 4, Vitreous quartz mass. 5, Blown sand accumulated in the wind-shadow. 6, Nubian sandstones and clays.

of milk-white quartz,* with no felspar and only a few minute flakes of biotite. The manner of occurrence of this mass (Fig. 10) leaves no

* The mass has been worked to a small extent, and some cut specimens can be seen at the north end of Philæ. But the rock is far too brittle to be of service in construction. It is usually shown to tourists by the local guides as "the alabaster quarry"—needless to say a totally faulty appellation.

doubt that it is an intrusion of the extreme acid portion of the aplitic magma. Similar quartz masses are common along with pegmatite dykes on the desert east of Philæ, beyond the limits of the map.

In the Cataract district, pegmatite generally occurs in dykes of very variable width, averaging 1 to 2 metres. These dykes cut the older plutonic and metamorphic rocks in all directions; they are generally easily visible from a distance, owing to their pronounced red colour contrasting with the darker rocks around them. The rock being somewhat brittle, is generally much broken up at the surface, and large broken felspar crystals strew the slopes near the veins. In some places, *e.g.*, east of the railway about the latitudes of Aswan and Sehel Island, as well as in the hills near Mahatta, the pegmatite is encountered in irregular intrusive masses and bosses rather than in well-defined veins; the surfaces of these masses are, like the dykes, covered with broken felspar fragments. It would appear that the marked degree to which breaking-up of the exposed portions of the veins and masses of pegmatite has gone on is mainly the consequence of alternations of temperature. The rock surfaces have frequently a temperature of 50° C. during the day, while at night they cool down to 15° C., or even lower. It seems that the coarse binary granites yield far more readily to these changes than the normal granites and syenites. The latter frequently split off in large masses, but seldom show any considerable amount of fragmentation. The difference may perhaps be due partly to the coarser texture of the rock and partly to the abundance of the felspar, with its high variation of expansion in different directions, combined with its persistent cleavage-planes. The resulting *débris* forms a coarse, red, felspathic sand, the fragments of which show brilliant cleavage-planes and are practically free from decomposition.

The pegmatite dykes north-east of Aswan, striking south-south-east in the micaceous schists and gneisses underlying the sandstone, are of somewhat different appearance to those in the rest of the district, being of a paler, almost milk-white colour, and contain red garnets 2 or 3 millimetres in diameter. One of the pegmatite-dykes cut through in the navigation canal north of the dam contained small strings of galena; but they were not found to thicken with depth, and the total amount of ore seen was insignificant. Specimens are preserved in the geological museum of Cairo.

The microscopic sections show both quartz and orthoclase to be in a very fresh state, but there is evidence here, as in most of the other igneous rocks, of much crushing. The crystals are often in a highly cracked condition, and a " mortar " of fragments surrounds the larger grains. The orthoclase is frequently altering to microcline.

On account of its lack of toughness as compared with granite, pegmatite is of no practical value as a building stone, even when it occurs in masses sufficiently large for quarrying.

VOLCANIC ROCKS.

The volcanic rocks represented at the Cataract are mica-diabase and basalt. The first-named appears from its manner of occurrence to have here more affinity with the plutonic series than with the volcanic; but it is described with the latter rocks in accordance with the usual classification. The basalt occurs only in dykes.

Mica-diabase.—In the excavation for the dam-foundation across the island of Thirmosia a mass of mica-diabase was cut through, commencing at 380 metres from the east end of the dam, and extending for 120 metres westward. A typical hand specimen, taken from the fresher part of the mass some metres below the surface, is a heavy (sp. gr. = 3.02), fine-grained, nearly black rock, with tiny glistening flakes of biotite, and small crystals of augite and hornblende (these are black in the mass); scattered among these dark minerals are white and colourless felspars.

Microscopically examined, the augite is of a very pale brown colour, slightly pleochroic; it is abundant, in allotriomorphic forms and rounded granules. The cleavage is badly seen, the crystals showing mostly irregular cracks (*see* Plate VIII., Fig. 4). The somewhat less plentiful biotite is brown, altering to hæmatite, limonite, and chlorite; the flakes are frequently nearly filled by the opaque iron oxides. Hornblende is only sparingly present as an accessory constituent. It is green in colour and forms irregular crystals with well-marked cleavages. The felspar, forming about half the rock, is in clear lath-shaped forms, which show repeated twinning and are frequently aggregated into radial groups (*see* Plate X., Fig. 1). The maximum extinction angle in sections perpendicular to the brachypinacoid is about 18°, so that the felspar is andesine. Apatite is relatively abundant, in well-defined hexagonal prisms.

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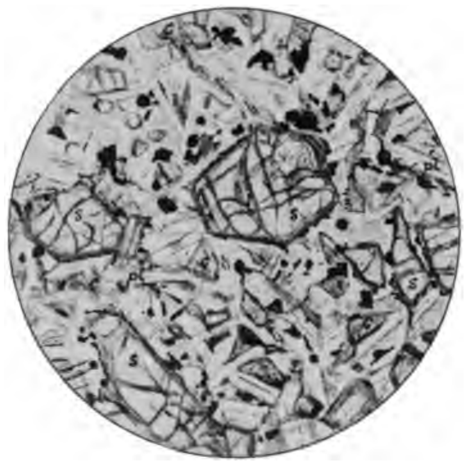

1. Radial grouping of plagioclase felspar (andesine) *pl*, in MICA-DIABASE, ASWAN DAM, as seen between crossed Nicols, x 35. *a*, augite; *b*, biotite.

2. DYKE OF MICA-DIABASE, NAVIGATION CANAL, x 35. A, from the centre of the dyke; *pl*, plagioclase; *a*, augite; *e*, enstatite; *b*, biotite, altering to chlorite with separation of opaque flakes of iron oxide; *ap*, apatite. B, from the more glassy zone at the sides of the dyke, showing porphyritic felspars in a cryptocrystalline ground-mass.

3. ALTERED OLIVINE-BASALT, FROM A DYKE NEAR KULLUTOT, x 35. *s*, serpentine formed along irregular cracks, with granules of magnetite, by alteration of olivine, of which last-named mineral no unaltered traces now remain, the clear spaces being filled with calcite (*c*); *d*, delessite (?), lining a cavity and enclosing a single crystal of calcite (*c*); *l*, labradorite, in lath-shaped forms, lying in a ground-mass of clouded chloritic and calcitic material; *m*, magnetite. No augite now remains, but this mineral possibly formed originally part of what is now the chloritic ground-mass.

4. ALTERED OLIVINE-BASALT, FROM A DYKE AT THE ASWAN DAM, x 35. *s*, serpentine (and pilite (?)), resulting from alteration of olivine, of which the crystal-form, but none of the original substance, is still preserved; *pl*, plagioclase felspar in lath-shaped forms, in a ground-mass consisting largely of calcite (*c*); grains of magnetite are scattered through the ground-mass and round the edges and cracks of the altered olivine.

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Where first excavated near the surface, the rock was found to be decomposed into a soft, clayey, micaceous and chloritic schist, but lower down it became fresher, though still containing thin, gently undulating bed-like bands of mica-schists, soft and watery. These bands were so soft as to be capable of being dug out with a spade. They were clayey, but on microscopic examination their more solid portions were found to consist of a fine-grained quartzose biotite-schist. The biotite seen in the harder parts of the bands is very fresh-looking, in tiny flakes, and, like the quartz, is doubtless of secondary origin. Evidently the bands are the result of crushing and sliding

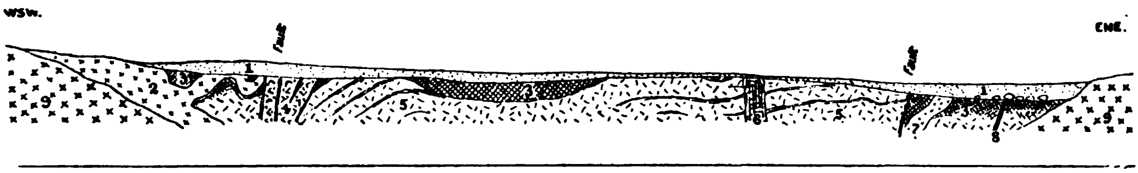

Fig. 11.—Section exposed during excavation for foundation of reservoir dam; the centre of section is about 450 metres from the east end of the dam, and the total length shown is about 200 metres. 1, Alluvium. 2, Fine-grained red granite. 3, Brecciated and watery micaceous and chloritic rock. 4, Pegmatite, with micaceous and chloritic breccia between the different masses. 5, Crushed mica-diabase, with watery bands of chloritic mica-schist along contorted surfaces of yielding; in its lower parts this passes into a grey pyroxenic gneiss. 6, Brecciated basic dyke. 7, Aplite vein, highly quartzose, resembling quartzite. 8, Basalt dyke. 9, Coarse-grained red granite.

of one part of the mass over the other. Subsequent permeation by water has aided the kaolinisation of the felspars and the chloritisation of the ferro-magnesian minerals, thus forming the clayey and chloritic matter.

The excavation of the trench for the foundation of the dam was carried ultimately to a depth of 10 metres in this rock before it was considered safe to build on. At the bottom of the exposure the mica-diabase appeared to pass into a hard grey pyroxenic and garnetiferous gneiss. No slide of this gneiss having been prepared, I am not yet certain whether it is merely a variation of the diabase, or a rock of different origin; in the latter case the diabase is in the form of a thick sheet. But there appeared no sharp demarcation, and I am inclined to think the two rocks are differently metamorphosed portions of a single magma.

Mica-diabase also forms a dyke 8 metres wide crossing the new navigation channel 215 metres north of the dam. Specimens taken from the centre of the dyke show almost exactly the same structure as the mica-diabase deposit last described. (Plate X., Fig. 2, A.) At the edges of the dyke, however, it passes into a diabase-porphyrite;

porphyritic crystals of plagioclase are seen scattered in a ground-mass consisting of glassy matter, with smaller crystals of felspar and biotite, and no augite or enstatite is to be with certainty detected.

Basalt.—Most of the basalt-like greenish-black compact rocks occurring as dykes at the Cataract are found on microscopic examination to be really fine-grained syenites, diorites, diabases, or porphyrites. At two points, however, there occur dykes of highly altered rocks which may somewhat doubtfully be referred to the true basalts.

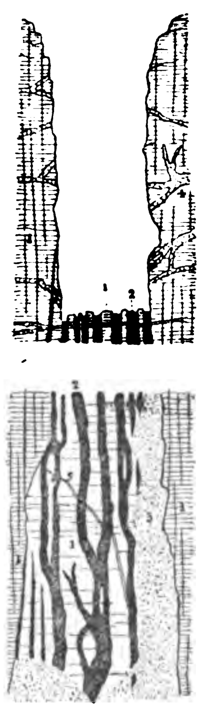

Fig. 12.—Cross section and plan showing dykes of altered basalt intrusive in granite gneiss, gorge near Kullutot. 1, Granite-gneiss, with secondary crush-planes perpendicular to the foliations. 2, Basalt-dykes, parallel with the secondary crush-planes. 3. Alluvium, partly hiding floor of gorge. 4. Veins of red granite, older than the basalt. 5, Quartz-veinlet, also older than the basalt. Total width of gorge about 8 metres.

One of these occurrences is in the floor of a very remarkable narrow gorge just south of the village of Kullutot, and a little beyond the south limit of the geological map on Plate II. Sketches of this gully are shown in Fig. 12. The gneiss which forms the country at this place is traversed by a series of vertical crush-planes at right-angles to the foliations, and the basalt has intruded itself into the cracks thus formed. The sandwiching of the mass has rendered it easy for the water, which occasionally runs down from the hills to the river after storms, to remove the upper portions of the basalt veins and the separating layers of gneiss, so that there results a steepwalled gorge, on the floor of which the dykes are visible.

Microscopically examined, the rock is a greenish-black one, of very fine grain, with greenish spots. Under the microscope (Plate X., Fig. 3), lath-shaped porphyritic crystals of plagioclase (labradorite) are seen in a clouded calcareous ground-mass which contains also the remains of larger crystals of olivine, now completely metamorphosed, and grains of magnetite. The olivine appears to have existed in large rounded grains, easily recognisable by the irregular cracks now marked by serpentine and strings of separated magnetite. The clear spaces between the cracks are mainly occupied by calcite, so that

possibly the olivine was one of the varieties rich in lime. The felspars are considerably altered, with much kaolin and calcite, and the crystals show specially strong alteration along cracks which traverse the slide in a constant direction irrespective of the orientation of the crystals; this latter phenomenon appears to be a result of crushing. There are also to be seen in the rock a number of comparatively large cavities lined by a pale-green mineral of low refractive index with a central kernel generally formed by a single crystal of calcite. The pale green mineral is very clear, and shows radiating fibres even in ordinary light, while between crossed nicols the radiating fibrous character is very marked. The fibres show straight extinction, but the interference colours appear higher than those of serpentine, and the mineral may possibly be delessite. No augite is to be seen, but the cloudy calcareous groundmass, difficult of examination, probably includes some alteration-products of augite and other minerals.

The second occurrence of altered basalt is in a dyke which crosses the foundation of the reservoir-dam obliquely at about 610 metres from its east end. The section of this rock (Plate X., Fig. 4) contains pseudomorphs of six-sided crystals which from their form and irregular cracks it seems difficult to ascribe to anything but olivine. No trace of the original substance however remains, its place being taken by a mixture of fibres of serpentine and another fibrous mineral (pilite ?) of rather higher double refraction; this latter polarises in yellows, while the serpentine shows only greys. In the cracks and round the edges of the crystals is finely granular calcitic material, with some strings of magnetite-grains; the separated magnetite is, however, much smaller in quantity than is usually seen to result from alteration of olivine, so that here again we are probably dealing with an olivine poor in iron and rich in lime and magnesia. Besides the idiomorphic forms, there are some rounded granules of the same altered mineral. Lath-shaped plagioclastic felspars, much altered, are abundant, with cloudy calcite and opaque magnetite, in a highly calcareous groundmass. The alteration of the rock has been so great that nothing remains of the original minerals except felspars and iron oxides.

METAMORPHIC ROCKS.

It has been already mentioned, in describing the igneous rocks, that at many points these rocks have taken on gneissose and schistose

textures as a result of crushing. Thus the coarse-grained red granite can be seen in every stage between the normal granitic rock as worked in the quarries, and the granite-gneiss which is so well exhibited in the narrow gorge near the great railway bend; the fine-grained granites show this passage into granite-gneiss even more commonly, as for instance on Sehel and El Hesa islands; the syenites and diorites change frequently into mica and hornblende schists; and the same change has taken place in the syenitic and dioritic laccolites near Bahr and on El Hesa island, as well as in the dykes at Bab and other points.

But to the east of Aswan, and also on both banks of the river in the south part of the district, there are rocks in which the gneissose and schistose character is far more pronounced, and which, from their advanced state of decomposition, as well as from their frequent penetration by the already described plutonic rocks, are manifestly of greater age than any rocks previously mentioned.

To the east of Aswan these rocks occur peripherally to the granite, and underlie the sandstone of the hills. They are well exposed, with nearly vertical foliation, in the railway cutting near Aswan station. They are friable grey mica-schists and sericite-gneisses, soft and crumbling owing to decomposition, and the resulting smooth slopes form a striking contrast to those of the less altered granites. Where, as frequently happens, they are cut through by pegmatite dykes, the red streak of the dyke is seen running sharply up the general grey slope, and is conspicuous even from a considerable distance.

The gneisses and schists of part of the area are much mixed up with the later granite, which appears to have been intruded into

FIG. 13.—Sketch of the rocks on the east side of El Hesa Island, from Ikeshema to near the south point of Biga, as seen from the east bank. 1, Micaceous schists and gneisses. 2, Fine-grained red granite, generally gneissose. 3, Coarse-grained red granite, weathered into rounded forms.

them in sheets (Figs. 12 and 13). They, like those further north, are characterised by great abundance of biotite, and are frequently so much decomposed that they can be dug out with a spade, or even with the hand, while where they are washed by the river the water-surface is at times covered by mica plates.

Gneiss.—At many points the gneissose texture of the acid rocks is so marked in the field that one is reminded of the typical gneisses of Saxony and elsewhere. The foliation is very distinct, and "eye structure" is not infrequent. But when specimens are submitted to microscopic examination, one finds that they are not true gneisses in the narrowest sense of the term, for the normal order of crystallisation of plutonic rocks is still preserved, though the crystals are cracked and broken, and secondary mineral-formation has gone on to a large extent. The gneisses are thus certainly crushed granites, and every stage between them and the normal granites can be traced. It is natural to suppose, however, that the more highly deformed portions represent older deposits than the more normal ones, and that the granites of the Cataract are thus not a single deposit, but a series ranging through a considerable difference of age.

Mica schist.—Next to the gneiss, mica schist is the commonest form of metamorphic rock of the district. The exposures are frequently so much weathered that it is difficult to get a specimen which will bear handling. A section cut from the less decomposed portion of a mass near Tengar (apparently one of the oldest rocks of the Cataract) shows the quartz and felspars to still contain the original minute enclosures of idiomorphic apatite and magnetite, though the biotite-flakes are arranged along the plane of foliation of the rock, and the quartz and felspar crystals show cracking and undulose extinction as signs of their crushing into new positions (Plate XI., Figs. 1 and 2). Thus the mica schist, like the gneiss, is really a deformed plutonic rock, quartz-mica-diorite or quartz-mica-syenite.

Cases of transition between mica-schist and hornblende schist are frequently met with, the rock in these cases resulting from the crushing of syenite or hornblendic granite (Plate XI., Fig. 3).

Hornblende schist.—The rocks which in the field seem to be true hornblende schists likewise prove on microscopic examination to be

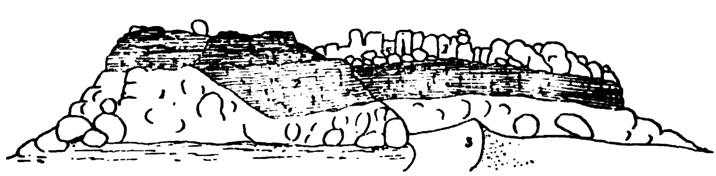

Fig. 14.—Rough sketch of crushed laccolite, hill in the north part of El Hesa Island. Length of hill about 200 metres. 1, Coarse-grained red granite, in characteristically weathered forms. 2, Hornblende schist, resulting from the crushing of a dioritic laccolite. 3, Sand dune.

merely crushed diorites. This is the case, for example, with a laccolitic mass in the north of El Hesa island (Fig. 14), and with some huge dykes in the hill-side behind the village of Bab (Fig. 15). As already

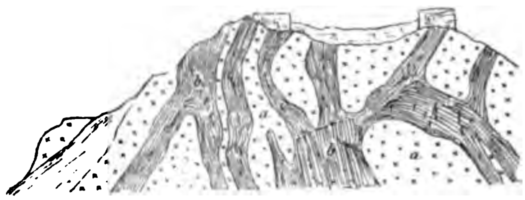

FIG. 15.—Rough sketch showing crushed basic dykes *b*, intrusive in granite and gneiss *a*, in the hill behind the village of Bab.

mentioned, true diorites are scarce in the Cataract area, and when found are generally passing into hornblende schist. But even in cases where the schistose structure is most marked in the mass the microscope reveals the original plutonic nature of the rock (Plate XI., Fig. 4).

The metamorphic rocks of the Cataract district have thus without exception been originally igneous masses, and their present texture is due to subsequent crushing.

IV.—General Conclusions, with Especial Reference to the Dynamical Evidences and the Physical Geology.

Age of the oldest Cataract rocks.—From what has been already stated on pp. 90–91, it will be seen that the igneous and metamorphic rocks are the oldest in the Cataract district. The direct evidences which can be gathered in the locality merely prove that these rocks are of pre-Cretaceous age; but there are several circumstances which tend to the conclusion that they had their origin in a period long antecedent to the Cretaceous. For, as has been shown above, the igneous and metamorphic rocks themselves do not belong to any one period; the schists and gneisses are older than the fine-grained granite, which in turn appears to be older than the ordinary coarse-grained granite and syenite. Then the pegmatitic intrusions are obviously younger than the granites, since they penetrate the latter; the pegmatite is in turn cut by intrusions of felsite and porphyrite; while these last rocks are penetrated by still more recent basalt and diorite-porphyry dykes. And since to even the youngest of these

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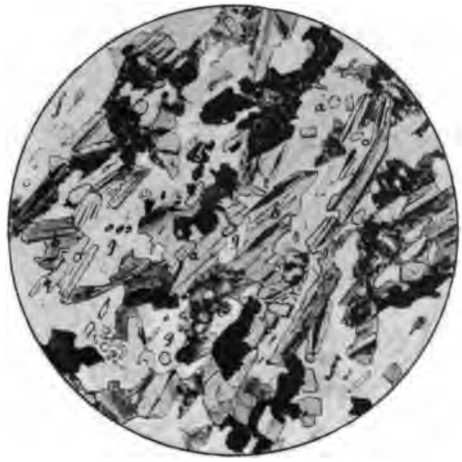

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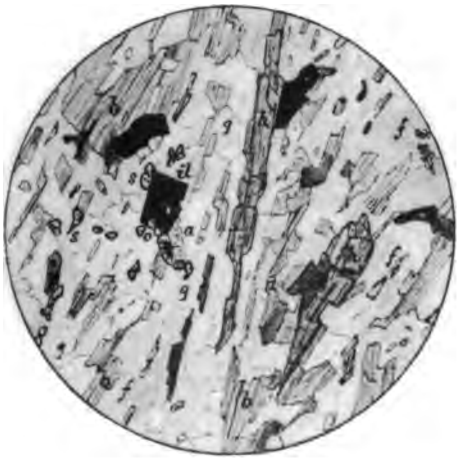

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1. CRUSHED QUARTZ-MICA-DIORITE, PASSING INTO MICA-SCHIST, TENGAR, x 35. (The section is cut from the least-altered portion of the rock.) *b*, brown biotite; *f*, felspar, mostly plagioclase; *g*, quartz; *a*, apatite; *z*, zircon.

2. CRUSHED QUARTZ-MICA-SYENITE, PASSING INTO MICA-SCHIST, FROM A LACCOLITIC MASS NEAR THE BLOCK-HOUSE NORTH OF KONOSSO, x 35. *b*, biotite, much altered, with separated flakes of iron oxides; *f*, felspar, mostly orthoclase, much decomposed; *g*, quartz; *a*, apatite.

3. CRUSHED FINE-GRAINED QUARTZ-MICA SYENITE, PASSING INTO HORNBLENDE-MICA SCHIST, WEST BANK OF THE NILE NORTH OF THE DAM, x 45. *g*, quartz; *b*, biotite; *h*, hornblende; *f*, felspar, mostly orthoclase; *s*, sphene; *il*, ilmenite; *a*, apatite.

4. CRUSHED DIORITE, PASSING INTO HORNBLENDE-SCHIST, AISANARTI, x 45. (The schistosity is not apparent in this slide.) *h*, green hornblende, in part arising from alteration of, or much intergrown with, augite (*a*); *f*, felspar (plagioclase); *ap*, apatite; *m*, magnetite; *g*, accessory quartz.

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igneous rocks we are bound to assign a pre-Cretaceous age (for the dykes at the Cataract always stop short of the Cretaceous sandstone and never intrude it), it follows that we must consider the schists and gneisses as considerably older than Cretaceous. Such a view is strongly supported by the fact that these older rocks have suffered a great amount of dynamo-metamorphism, the changes being the greater the further we go back in the series outlined above; thus the granites, for instance, frequently show two or more distinct sets of foliation and crush planes (Figs. 16 and 17).

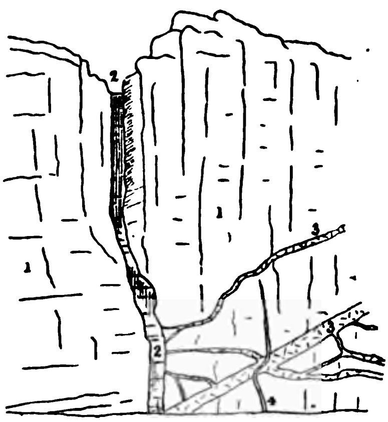


Fig. 16.—Sketch of dykes in granite-gneiss, north side of canon near Kullutot. 1, Granite-gneiss, forming walls of cañon. 2, Quartz-porphyrite dyke, 1 metre wide. 3, Red granite-veins. 4, Younger granite vein.

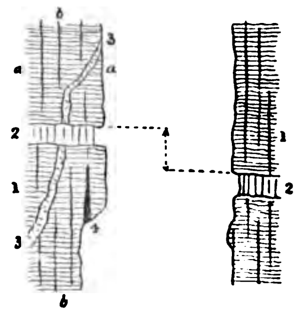


Fig. 17.—Sketch horizontal section of cañon, showing displacement of the quartz- porphyrite dyke on the two sides by faulting. 1, Granite-gneiss; *a-a*, planes of foliation; *b-b*, planes of subsequent crushing and faulting. 2, Quartz-porphyrite dyke. 3, Granite vein. 4, Basalt dyke.

The oldest rocks of the series bear, in fact, far more resemblance to the Archæan rocks of North America than to more recent deposits. It is true that strong metamorphism is also sometimes shown by rocks of comparatively late age, but in such cases the rocks usually form part of a still existent mountain-mass, such as the Alps; whereas here the mountains, if such were formed, had been worn down before they were partially submerged by Cretaceous waters. Support to this view of the great age of the bulk of the igneous and metamorphic rocks is also given by comparisons with deposits nearer home than North America. The recent work of the geological survey in the Eastern Desert and Sinai has shown the igneous and metamorphic rocks in those districts to have a general similarity with those of the Cataract,

and the same sequence among them is traceable.* In Sinai the sedimentary rocks overlying the igneous and metamorphic ones are Carboniferous, and though in Sinai a few intrusions into Carboniferous rocks, and in other places even intrusions into Cretaceous ones, undoubtedly occur, still, these are so exceptional † as to lead us to regard them as of the nature of small disturbances after the formation of the main masses rather than as indications that the eruptives and metamorphics as a whole are of a later age than the sedimentaries.

Outline of the geological history of the Cataract.—An Archæan, or at least Palæozoic, age being thus assigned with probability to the main igneous and metamorphic masses of Egypt and Sinai, and the portion of these rocks occurring at the Cataract exhibiting characters which justify us in regarding them as belonging to the older parts of such masses, it may be well, having thus obtained a provisional starting-point of geological age, to outline as far as possible the geological history of the Cataract district.

The history opens with the deposition of the igneous rocks which now form the *gneisses and schists* in the peripheral portion of the areas. Whether or not these formed the original crust of consolidation of the earth is not certain; but the microscopical examination proves an igneous and not a sedimentary origin for them. The contraction of the earth's crust led, at an early period, to the compression of these rocks, producing the foliated structure which is now one of their most marked characteristics. This foliation was apparently followed by intrusions of the *fine-grained granite*, partly in sheets coursing along the foliation planes (which usually strike north-northwest and dip strongly westward, frequently approaching verticality), and partly in irregular masses. At a later epoch the *coarse-grained granite* was forced in among these older rocks; from the size of its crystals we infer that this granite consolidated probably at a great depth below the surface, and its present-day exposure shows that great denudation effects have followed its deposition.

Next, the compound mass was crushed by the continual contraction of the crust, converting much of this rock into gneiss, and still further altering the surrounding masses, while dykes and irregular masses of

* Barron and Hume, "Topography and Geology of the Eastern Desert of Egypt," Cairo, 1902, p. 226.

† Ibid, p. 199.

coarse pegmatite were forced into cracks in it. The coarseness of the pegmatite shows a slow crystallisation, from which it is probable that a large superincumbent mass may have still covered the rocks now exposed. Further compression, with the production of faults and fissures, followed, and *felsite and porphyrite* dykes were injected into these latter; while at a still later date *more basic dykes and laccolitic masses* of basalt, diabase and porphyrite were intruded. Signs are not wanting, in the fineness of crystallisation of these rocks (especially at their edges) to show that the felsitic and basaltic dykes were intruded at a period when the surrounding masses were cool and relatively unburdened. We infer long denudation between the formation of these and of the earlier pegmatite dykes, and the latest of them were probably formed in the Cretaceous period. The movements which caused all the foliation, fissuring, and faulting probably raised the earth's crust into mountain ranges, the core of the Red Sea hills and the Sinai peninsula still remaining as evidence of these. But in the Cataract district these ancient elevations were planed down by denudation into mere stumps, and the Cretaceous sea or estuary gradually covered them with *conglomerates, sandstones, and clays.* It is most likely that the sea encroached gradually southwards, so that while successively deeper-water deposits accumulated to the north, the shallow-water conglomerates and grits were deposited in successively lower latitudes. The material of the sandstones may well have been derived from the denudation of mountains to the south, composed of similar igneous rocks to those which now occupy the Cataract area. The presence of beds of oolitic ore near the monastery of St. Simeon indicates that lacustrine conditions may have prevailed for a part of the time during which the sandstones and clays were being deposited.

Subsidence continuing after the deposition of the Nubian sandstone, the Cretaceous and Eocene seas rolled over what is now the Cataract area; the thick beds of *clays and limestones* which they deposited have disappeared in subsequent denudation-periods, but at Jebel Garra, only 34 kilometres west of the Cataract, a thickness of over 300 metres of these marine accumulations conformably overlies the sandstone, and these beds must have extended over where the Cataract now is.

About the end of the Eocene period came a great elevation of this part of the earth's crust, and what had been the sea-bottom became dry land. It was after this elevation that the Nile had its origin, though the river probably did not occupy its present channel until the Pliocene period, when considerable earth-movement and faulting took place in north-east Africa. To this period of disturbance belong most of the faults which have determined the main features of Egypt at the present day, including a number of well-marked dislocations in the desert close to the east of the Cataract, which do not, however, fall within the area of the map, and have not yet been surveyed. Some information concerning these faults was gathered by the writer in traversing the desert between the main stations during a triangulation of Lower Nubia in 1902. One of the most marked cases is that observ-

Fig. 18.—View of fault exposed in a wadi on the road from Aswan to El Hadir.

able on the road from Aswan to the El Hadir water-holes, where in a wadi at a point 6 kilometres east of Aswan the ancient schists are thrown up at least 40 metres by a fault which cuts through the hill, striking a little north of east. Fig. 18 shows a photograph of this

exposure; the rocks to the left of the fault are entirely sandstone, those to the right being grey schists. Other examples, almost equally evident in the bareness of the desert, can be seen between this one and Jebel Kurtunos; the fault close to the west face of Jebel Kurtunos strikes nearly north and south, with a down-throw to the west of about 61 metres (*see* Fig. 19, which is from a section levelled while occupying the hill as a trigonometrical station).

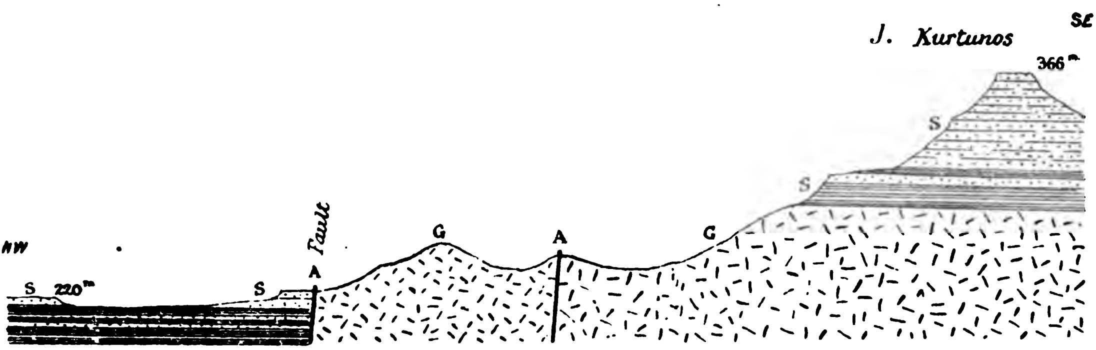


Fig. 19.—Section showing fault at Jebel Kurtunos. Scale 1/5000. *G*, granite; *S*, Nubian Sandstones and clays; *A*, aplitic dykes, one of which forms the fault-plane.

Faults at the Cataract.—Several well-defined faults can be traced within the mapped portion of the Cataract district, and two of these are of special interest as having probably originated, or at least as having been planes of further movement, since the Nile occupied its present position. One of them passes north-east up the gully situated about 600 metres south of the east end of the dam, and over the plateau (where it can be easily traced in a depression) into the ancient Nile-course; the strike of the fault is not quite a straight line. The other fault runs from near the village of Koror, striking a little north of east through the plateau, where it cuts the first fault in the depression above referred to. The down-throw in the first-named fault is to the north, in the second to the south; so that besides the main dislocation due to the first fault there is a wedge-shaped portion between the two which is let down. It is difficult to trace the faults across the islands, owing to the absence of sandstone; or on the west bank owing to blown sand obscuring the scarps. It is not impossible that a fault of the same period may follow the present west channel of the river so as to limit this wedge westward; slickensides and other evidences of motion were specially numerous in this part of the channel when laid

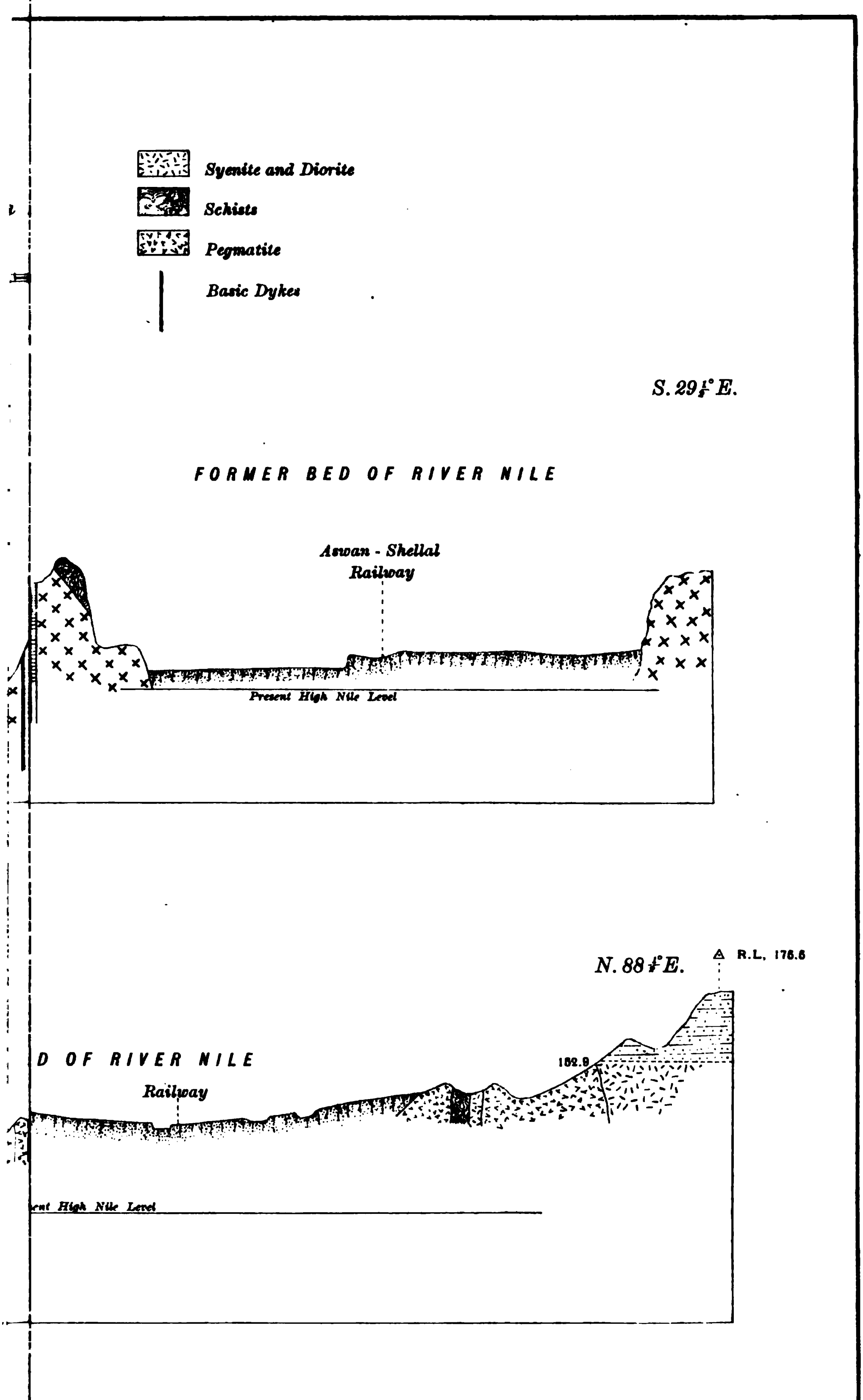
dry for the excavation of the dam foundation, and the straightness of the west channel for a long distance is suggestive, as is also the lowness of the limit between sandstone and granite along the west bank. But there is no absolutely clear evidence to show that this fault was not, like the scores of others in the granites and schists, produced long before the sandstone was deposited.

The two transverse faults just mentioned have been crossed by two carefully levelled sections (AB and EF on Plate XII.), and the throw measured. In the shorter section, taken near the junction of the two faults, the sandstone in the wedge has its basal beds thrown down 14 metres in the north fault and 16 metres in the south one, the base of the sandstone in the wedge being at 126 metres above sea-level as exposed on both sides of it. In the longer section, the base of the sandstone in the wedge at its south side is at 126 metres, while in the adjacent hill-mass it is at 150 metres, indicating a throw of 25 metres; considerably more, that is, than in the shorter section; the north side of the wedge has the junction of sandstone and granite at 117 metres above sea-level, but there is no sandstone near enough on the up-throw side for an accurate measure to be here obtained of the amount of throw. The nearest sandstone on the line of section has its base at 135 metres above sea-level, so that if we may judge approximately from this, the throw is about 18 metres.

It is thus clear that the reservoir dam is situated on a wedge-shaped mass which has been faulted down on the average about 18 metres below the country north and south of it. A glance at the map will show that this includes some of the lowest-lying lands in the Cataract area, notably the tract of Thirmosia and the adjacent islands. The limits of the wedge have not, for reasons just mentioned, been traced across the river to the west bank; but if we assume them to continue in straight lines, they include at least a part of Awad Island and the one solitary patch of sandstone of all the Cataract islands. The igneous hills of Sehel to the north, and of El Hesa to the south, rise far higher than the base of this sandstone-patch on Awad.

Besides the main faults just described, there are some smaller ones, striking transversely to the river, and involving both the eruptive rocks and the sandstone, exposed on the east bank opposite Saluja

Plate XII.



Syenite and Diorite
Schists
Pegmatite
Basic Dykes
FORMER BED OF RIVER NILE
Aswan - Shellal Railway
Present High Nile Level
R.L. 176.6
182.9
D OF RIVER NILE
Railway
ent High Nile Level

Island. Though having only a throw of a few metres, these may nevertheless have had considerable effect in facilitating the erosion of cross-channels by the river. Of the very numerous smaller faults which involve the igneous rocks alone, and not the overlying sandstone, the greater number are probably pre-Cretaceous, and thus much older than those just described.

Since some of the faults in the Cataract district are shown to have been produced in comparatively recent geological periods, and since a number of faults are crossed by the Nile dam, the question may be asked whether there is not a possibility of further earth-movements along these existing planes of shearing, involving risk to the structure which passes over them. The answer is that although the possibility of such movements cannot be denied, yet there is no evidence that they are taking place in our own day, and there is no reason to fear any continuous slow movement. Should an earthquake of any magnitude take place, a shift would occur more easily along the existing planes of weakness than elsewhere; but it is most probable that a shock powerful enough to produce such movement would in any case damage the structure, even did no faults exist.

Though the site of the Nile dam was determined on prior to the geological survey of the district, it may be noticed with satisfaction that the results of the survey do not indicate any probability that a better site could have been chosen within the Cataract area. The entire district has suffered enormous crushing, and probably every channel of the river, and every tract of alluvial covering within the district, occupies the site either of a fault, fissure, basic dyke, or band of decomposed rock. It follows that any line whatever, straight or curved, which crosses the river within the Cataract area, must pass through these lines of weakness; and contrary to what has been urged,* the curved dams which were originally suggested in place of the straight one finally adopted would in the writer's opinion have had no better chance of avoiding the weak places. That more small faults have been noted along the lines of the dam and navigation canal than elsewhere, is simply due to the better facilities for examination given by the enormous excavations and the laying dry of tracts which would otherwise have been hidden from geological observation.

* Willcocks, "The Nile Reservoir Dam at Aswan and After," London, 1901, p. 7.

Ancient course of the Nile.—We have the strongest possible evidence that the Nile formerly flowed through the wide valley which detours east of its present course, and also through the narrower hollows nearer the river, in which the ordinary Aswan-Shellal road and the ancient wall are situated; for all these depressions contain thick deposits of river silt, and the course of the river above and below the Cataract exhibits far more continuity with these old channels than with those of the present day. The silt deposits in the wide valley occupied by the railway line are partially covered with superficial deposits of a coarser nature, the product of disintegration and down-wash from the surrounding hills; but below these the ordinary river-silt is found. Further, the levels of the silt deposits in these ancient channels are far above the high Nile levels of to-day. The highest point in the wide eastern valley occurs near the great bend in the railway, slightly north of the latitude of the dam and present-day cataracts and on the up-throw side of the fault just mentioned; the level is here about 127 metres, whereas the high Nile of to-day reaches only 98 metres above the sea-level. Even assuming that the uppermost few metres in the valley have been deposited since the river followed this path, we cannot avoid the conclusion that the river formerly occupied these channels at levels 20 metres or more above its present level; and further evidence of this is found in the ancient water-marks 18 metres above the present high Nile, mentioned on p. 53.

Causes of the changes in the river.—What causes, then, have operated to cause this change of path and level of the river? This question cannot be completely discussed without reference to the possible changes in the river's course above and below the Cataract which may have preceded and in part conditioned the changes of level at the Cataract itself. Up-stream, we find a narrow gorge at Kalabsha, cut deeply through crushed igneous rocks, and farther up at Wadi-Halfa a long stretch of cataracts where the river is split up into innumerable channels. It is obvious that considerable erosion and lowering may have gone on here within a few thousands or tens of thousands of years; the gorge at Kalabsha has, in fact, given soundings * which indicate that a waterfall once existed there and has disappeared by continued erosion, though nothing exists which enables us to fix

* Ball, Q. J. G. S., Vol. 59, p. 75.

even an approximate date for such disappearance; at Wadi-Halfa, in the great "belly of rock," the waters rush with such velocity as to be able to sweep along large rock-fragments, and are divided into channels so numerous as to present a very large surface of attack, while their erosive power is still further increased by the very irregular courses followed, so that though its rate is not recorded, the most casual observation leads to the conclusion that erosion is there proceeding relatively quickly. There is, indeed, a temple near Halfa whose floor, 5 metres above the present high Nile level, shows signs of flooding since 1,100 B.C.,* but this may well have been an exceptionally high flood from which no general conclusions can be drawn. It is, I think, only at Semna, some 70 kilometres up-stream of Wadi-Halfa, that sufficient data exist for an estimation of the average rate of erosion over a long period; at this point a hard gneiss barrier has been cut through at such a rate as to lower the river-level by an average of 2 millimetres per year during 4,200 years. At Semna the river is obstructed, though for a very short distance along its course, to a far greater extent than is the case at any cross-section at either the first or the second cataract, so that the vertical erosion there may well be in excess of what it is at other places; but, nevertheless, an erosion of 2 millimetres per year might, in so fluctuating a river as the Nile, and in such desolate places as the cataract, go on for a long period without attracting notice in the absence of precise records—and no such records exist at other points than Semna, so far as is known. Had it not been that the engineer-kings of the twelfth dynasty had sculptured a long series of high-Nile marks on the rocks at Semna, the vertical erosion of 8 metres in 4,200 years, which we know now to have there taken place, would have remained unproved and perhaps unsuspected.

The question of a lowering of the Halfa Cataract by erosion is of importance, since any lowering there may have influenced the inclination and velocity of the stream, and consequently the erosive power at the Aswan Cataract; but it is important to remember that the rocks are similar at the two cataracts, and if no outside forces have supplemented the erosive action of the water, the erosion at the two points will have proceeded at similar rates, and thus the inclina-

* Lyons, Q. J. G. S., Vol. 50, p. 544.

tion of the stream will have remained unaltered. It is otherwise when we consider the complete disappearance of a barrier like that which must have existed at Kalabsha. The river, cutting gradually backward in its fall over the igneous ridge, eventually cut right through it, and then the barrier being removed, the velocity of the stream below was increased in the same way as that in a canal is increased when a lock is opened. It is, however, probable that the Kalabsha waterfall was a thing of the past at a period so remote as to justify us in leaving it out of account in discussing the existing cataracts.

Let us now consider the evidences which exist at a point 60 kilometres down-stream of the first cataract, viz., at *Silsila*. This district has not, unfortunately, yet been geologically surveyed,* but enough is known of it to form a general idea of what has happened there, and we find a surprising similarity to the record at Aswan, with the difference that at Silsila, the rocks being less resistant, the cataract-phase has been completely passed, and the river now flows without rapids, though its velocity is locally increased by the narrowness of the gorge through which it passes. On the east bank, however, is a wide alluvial plain which shows that at Silsila, as at Aswan, the Nile formerly occupied a sort of loop-channel to the east instead of its present bed, and the river-level is now 20 metres or more below its former level. This similarity of occurrences at Silsila and Aswan leads us to seek for a similarity of causes. It appears unsatisfactory to dismiss the question of change with the easy explanation that the river has in the course of its history simply eroded the softest of a number of channels more deeply than the rest and then ultimately occupied this deeper channel only. For at Aswan at least, there does not appear to be any greater resistance in the rocks of the old channel than in those of the new, and moreover, the old channel conveying the bulk of the water with its eroding tools—the suspended matter—would be the seat of greatest erosion. We are driven to seek some other, or at least some contributing, cause in explanation.

It will simplify matters somewhat if we can fix an *approximate period for the changes*. A limit in point of lateness is afforded by historical data. Thus the cutting of a canal at Sehel shows that the river occupied its present channel at the Cataract during the twelfth

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* See footnote to p. 105.

dynasty; while the ancient quarry-roads and the inscriptions along the Aswan-Shellal land route indicate that this was dry land in the time of the early empire, and it can hardly be doubtful that the change of course and level took place before the dawn of history. There is more difficulty in fixing the older limit. The Nile appears, however, not to have occupied its present channel till late Pliocene times, and the ordinary Nile alluvium such as fills the ancient channels at the Cataract is of Quaternary origin.* In early Quaternary times the Nile may have differed largely in volume and inclination from the present river, but the general characters of the deposits which now fill the ancient channels at the Cataract show them to belong to the latter part of the Quaternary, when conditions were approximating to those of to-day, and when the river was depositing silt in the more deeply-eroded channels of the pluvial period. We thus conclude that the changes at Aswan and Silsila, though pre-historic, did not precede the historical period by a very long interval.

It has sometimes been thought that in the golden days of Egyptian history the cultivated lands extended over parts of what is now desert, and that the Nile was in early historical times a greater stream than now. It is of course true that some areas may now be untilled which were formerly cultivated; but these are in the valley, and the hills limit this in such a way as to render it impossible for us to think that the amount of cultivation was very much in excess of what it is at the present day. Take, for instance, the Cataract district itself; we know that it was formerly the site of important cities like Syene and Elephantine, and it has been imagined that the cultivated lands of the district were then larger than the few thousand acres of to-day. But the evidences are entirely against this supposition. Where could such lands have been situated, if not on the hills? And if on the hills, how were they irrigated, and where are the remains which they must have left had they existed? Climatic changes may be slowly going on, and the Cataract, like Egypt in general, may once have been a rainy district; but this was certainly not the case in historical times; the evidences of the deserts are overwhelmingly opposed to the supposition that climate in Egypt has changed per-

* Blanckenhorn, "Die Geschichte des Nilstroms in der Tertiär und Quartärperiode.' Zeitsch. der Gesellsch. für Erdkunde, 1902, pp. 694–722.

ceptibly within the historical period, or that the Nile has diminished appreciably in average volume. Where temples exist along its course, they may in some cases be now at greater heights above the river than formerly, as at Wadi-Halfa; but these are explainable by erosion of the channel; and at other places, *e.g.*, the temple of Luxor, the structures are now flooded by the Nile, which would afford evidence, on the same basis of argument, for the reverse conclusion.

We must therefore conclude that the *volume* of the Nile has not sensibly diminished within historical times, or, say, within the last 8,000 or 10,000 years. The *inclination*, and consequently the velocity, of the river has diminished somewhat during that period, as shown by the changes in the delta and the partial submergence of the temple of Luxor; these changes are in the direction of a rise of water-level, and thus the opposite of those at Silsila and Aswan. It has been mentioned above that in the reaches above Aswan the erosion at the two lowest cataracts at approximately equal rates will have maintained a constant inclination if no other forces have acted. If we assume the fall of 20 metres at Silsila to have taken place, by whatsoever agency, during the same period as the almost exactly equal lowering at Aswan, the same would be true of the down-stream portion of the river. If the fall at Silsila took place entirely or in great part before that at Aswan, the effect on the erosive power of the stream north of Aswan may well have been considerable; but there is no evidence to prove this to have been the case. And though change of inclination would affect the rate of erosion and thus account for more or less rapid changes of level, it would not account for the change of the river's course; for it would appear far more natural for the erosion to have acted in the ready-made river-bed than to form new channels in rocks of equal hardness.

There remains the possibility of earth-movements; these alone appear to be capable of explaining the migration of the river in the cases of Aswan and Silsila. It will be noticed that the highest part of the old Nile course lies about in the prolongation of the line of the Aswan dam, which is itself built across the stream at the point of greatest throttling of the waters. It will be noticed, too, that this highest point is on the up-throw side of a fault, and that the wedge-shaped mass which has been let down by the two faults mentioned on p. 97 occupies such a position, that if it were raised up through

a height equal to the throw of the fault, or perhaps a few metres more, the Nile could be turned back into its old channel, and the Cataract as we now know it would be dry except in high floods. The fact that if the motion which has taken place at these faults could be reversed so as to bring the rocks into the same relative positions as they occupied before the folding, the river would certainly follow its now dry ancient bed instead of its present channel, leads almost irresistibly to the conclusion that the faults must have caused the change in the river's path. It follows, if this be accepted, that the faults belong to the Quaternary and not to the Tertiary period, and are thus amongst the youngest faults known in Egypt.

There are no sufficient data for any precise statement as to the cause of the similar change at Silsila; but the evidence of low limestone hills there in the midst of a sandstone district * seems to point to faulting, and thus a parallelism of cause, as well as of effect, is probable. †

Our belief in the faulting as the cause of the river's change of path is not lessened if we attempt to read, from the field evidences, what may have been the history of erosion in the Cataract district before and after the faulting. The fact that every low-lying portion of the old dry channels is full of silt-deposit forbids the supposition that there was any violent rapid or great inclination of the river-bed when it occupied those channels. If the Nile could be turned through the old channel now, the section in Fig. 20, based on levels taken by Hawkshaw,‡ shows that a rapid fall would take place; but this would be due partly to the circumstance that the ancient deposits have been removed by recent downwash from the south and north ends, while the height of the central portion has even been slightly increased by recent detritus; and in still greater part to the fact that the same faulting which let down the wedge-shaped area near the dam also raised the central part of the old Nile bed. The Nile probably flowed

* See the map on plate II of Sir W. Willcocks' "Egyptian Irrigation," 2nd ed., or better, the larger plan of the Silsila district in the Atlas of Plates to the "Report on Perennial Irrigation and Flood Protection for Egypt." Cairo, 1894.

† Beadnell and Hume have lately found that these appearances are due to a fault of great magnitude, the Eocene and Cretaceous limestones having been faulted against the Nubian sandstone. The northern boundary of the Kom Ombo plain has been determined by this line of fracture. (See Beadnell, Q.J. Geol. Soc. London, vol. LXI, 1905, p. 670).

‡ Q. J. G. S., 1867, pp. 115–119.

peacefully through the ancient channels for a long time previous to the change, and while the bulk of the stream followed the wide eastern

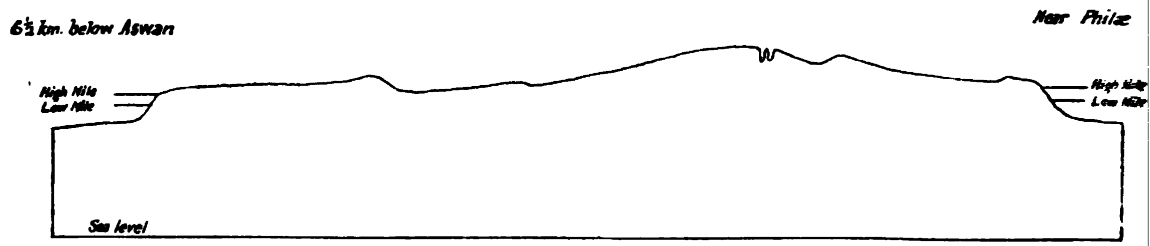


Fig. 20.—Section along the old Nile-bed from near Philæ to about 6 kilometres below Aswan. Vertical scale 50 metres to 1 cm. Horizontal scale 1 km. to 1 cm. (After Hawkshaw).

valley, it is possible that smaller streams followed the present-day channels, then situated at a higher level.

The letting down of the wedge would, of course, condition the change only on the supposition that sufficiently low passages existed down-stream of the wedge to permit of the waters having an outlet through them. But it is not necessary to suppose that these passages were cut previously by the river itself; the portion of the river's present track between Aswan and Koror may well have been a "khor" such as are found running into the Nile valley at many points both in this district and elsewhere. The floors of such khors are frequently very little above the Nile-level for long distances up from their mouths, and they often pass round isolated rock-masses such as would be formed in the present case by the hills of Sehel and Saluja. Prior to the faulting, then, a khor or wadi, with its head somewhere near the dam, entered the Nile valley near where Elephantine now is. The faulting down of the wedge beheaded this khor, and the Nile forsook its old and now raised channel and flowed down the lower path offered by the khor. The erosion at this period must have been enormous; in the khor was doubtless abundant broken-down material in large angular masses, such as abound in every khor in the district to-day; the rocks on the sides of the khor would be cracked and separated into blocks; and the access of a mighty stream would be all that was necessary to start thousands of nature's mills grinding out the channels. The actual details of the sculpture were largely influenced, both in the dry khor and in the subsequent river-channels, by differences in hardness of the rocks, and especially by the existing basic dykes and fissures.

Nearly every one of the deeper channels can be traced as following the line of a crushed and easily-removed dyke, or a highly crushed and sandwiched mass of granite, or a soft schist. The selective power of water in choosing the most easily-eroded channels for itself has seldom been brought home more forcibly than in the excavations for the Nile-dam foundation, where many thousands of pounds more than were anticipated had to be spent in sinking in the soft, decomposed rocks in which the river had cut its way, leaving the intervening hard granite high and dry. So long ago as 1867, Hawkshaw had remarked the influence of dykes of basic rocks on the river channels, and recent researches have only confirmed and extended our knowledge of such influences.

Soundings of the Nile-depth have been confined to small portions of the Cataract district. Plate XIII shows the result of numerous systematic soundings of the west channel between the Bab Hemedai and the north end of the navigation canal; it will be seen that over a comparatively large area the bottom is over 40 metres below the mean water-surface. The deepest sounding gave the level of the bottom as 42.1 metres, which is about the same as the ground-level near Minia, over 650 kilometres down-stream. It is scarcely thinkable that these great hollows can have been excavated by such rapids as exist at the present day, though the currents are still sufficient to keep them from getting silted up. But they are easily explained by the history of the region outlined above. The immense rush of water into the beheaded khor would cause an erosion sufficient to account for all the excavation observed. Pot-holing on a gigantic scale would be the natural consequence of a great waterfall such as must have existed here.

It will be remarked that the theory of the faulting down of a portion of the cataract valley, while explaining the *migration* of the river westward, does not in itself account for more than a small proportion of the *lowering* of the river-level. Such lowering is almost entirely due to *erosion*, though the course of the erosion and its intensity were conditioned by the faults. The river has pursued substantially its present course for at least 10,000 years, and every moment, night and day, winter and summer, throughout this long period, the river has been grinding down its channel. Even at the present day, the erosion must remove an enormous amount of rock each year; the

velocities in the rapids are such as to move stones weighing tons, and not less than 50 million tons of suspended material, much of it capable of abrasion, is carried over the river-bed by the 94,000 million tons of water which pass Aswan in the course of an average year, while immense numbers of pot-holes are being eroded in the hardest rocks by eddying-currents acting on sand and stones lodged in the hollows of the surface. Continually honey-combed by pot-holes, and penetrated by joints and crush-planes, the hardest masses of granite are being broken up and carried away by the annual rush of flood-waters.

The great part played by potholing action in river-erosion through hard rocks has only lately received the attention it deserves. In an interesting paper published in 1902, Prof. Brunhes * has given the results of some careful observations on this feature of erosion at the Aswan Cataract. From a study of the islands near Elephantine, especially of the small islet which he has named Ilot des Marmites (Pot-hole Island), he concludes that the actual grinding is performed, not by large stones, but by sand carried round and round by the water-eddies; he further shows that pot-holes in an intermediate stage of their formation have a more or less conical projection rising from the bottom, like the bottom of a wine-bottle, while a completely rounded bottom is indicative of cessation of the action, due to secondary movements prevailing over the principal eddy as the depth increases. So profoundly is Prof. Brunhes impressed with the importance of pot-holing action in the erosion of river-gorges, that he boldly proposes † to classify all gorges by comparing them with a pot-hole-formed gorge as a prototype; he points out that unless the rocks are hard, the pot-holes will not be persistent, and that it is only in exceptional cases that we can expect to find them preserved. While we may not be able to go the whole way with him in this broad generalisation, there can be no doubt that Prof. Brunhes is right in attributing the main part of the river-erosion at Aswan to pot-holing.‡ Though the time required to grind out a single pot-hole may be long, the number of holes in progress at the same time makes up for the slowness of develop-

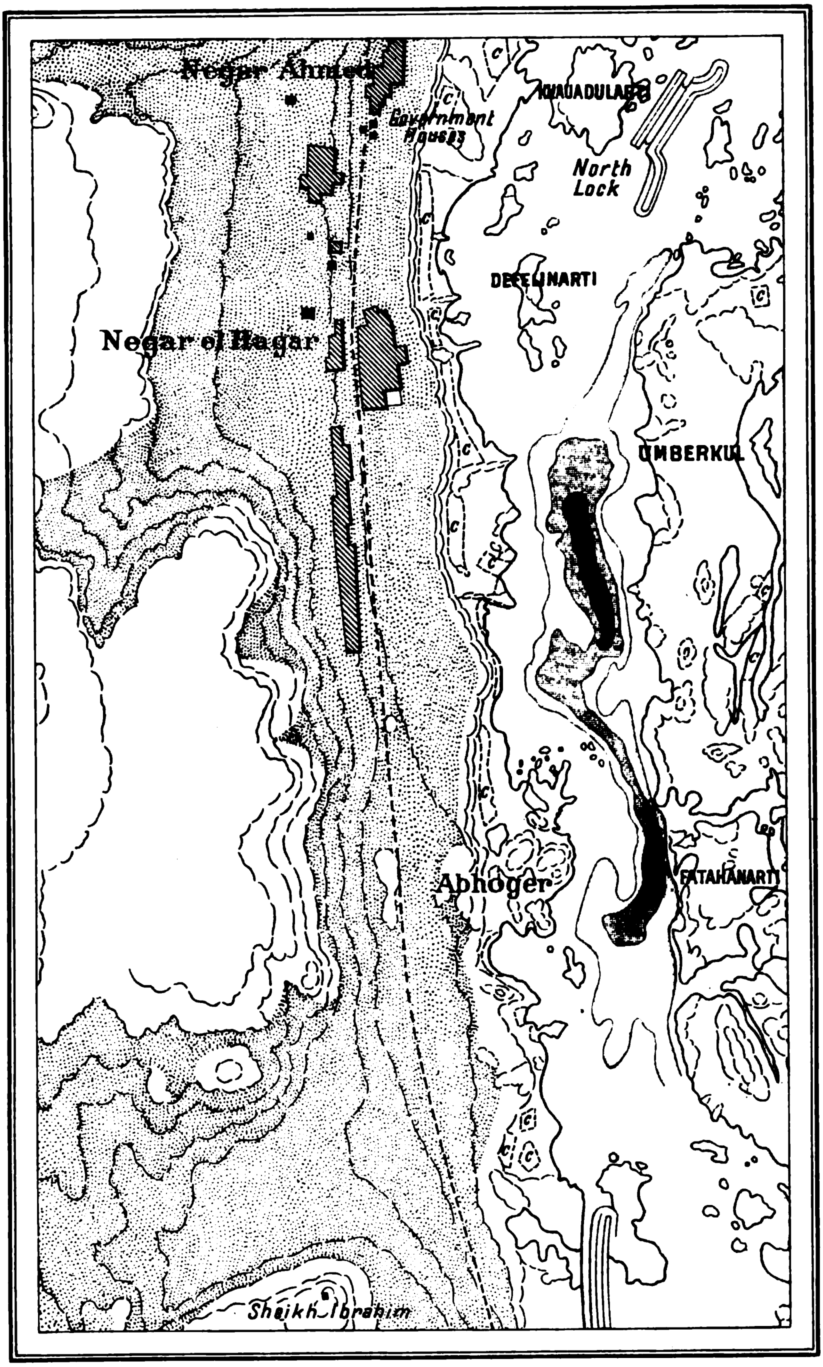
* "Le Travail des Eaux Courantes," Mem. Soc. Fribourgeoise des Sciences Naturelles, Fribourg (Suisse) 1902, pp. 153–178.

† Comptes Rendus, Paris, 1902.

‡ The author came to the same conclusion in the case of the Semna Cataract.

Map showing Results of Soundings in the West Channel between the North Lock and the Navigation Canal.

Scale 1 : 10,000



Depth 0 - 15 m. below low Nile level (R. L. 85 m.)	
15 - 25 m. " "	
25 - 35 m. " "	
over 35 m. " "	

Greatest recorded depth 42. 1 m.

ment of individuals. It is not possible to give more than a guess at the total number of pot-holes in progress at the Cataract, for they are mostly only visible when the river is low, while many are doubtless continually submerged; but Prof. Brunhes states that he examined about 400, and the total number must be hundreds of times greater than this. And though we have no means of forming a precise estimate of the rate at which erosion is proceeding at Aswan, it appears from the above considerations that it is by no means impossible that the average rate for the last 10,000 years or so may have been equal to the rate which has actually been recorded at Semna, viz., an average lowering of the entire water-swept area of 2 millimetres per year. Such a rate would account in 10,000 years for a lowering of 20 metres, which is about the actual fall since the great change took place in the river's course. Thus the fall of the Cataract at the commencement of the historical period may well have been considerably greater than its present 5 metres, and the statements of classical writers * regarding it may be in reality less exaggerated than they appear from a comparison with what can be observed to-day. At the time when Diodorus Siculus visited Egypt (B.C. 20), the rate of erosion supposed above would give a fall of about 9 metres, or nearly double the present one, if we assume the erosion to have been mainly confined to the crest of the rocky barrier. It may be objected that there is no proof that erosion has taken place at Aswan at the same rate as at Semna, and certainly the narrowness of the Semna barrier and the extraordinary contraction of the river there appear to support the idea that the Semna erosion may be phenomenally rapid. But we may set off against these differences the inferior resisting power of the dykes and softer rocks of the channels of the first Cataract as compared with the hard gneiss of Semna, and the probability that the tectonic movements at Aswan may for a time have considerably accelerated the erosion. And if in the present day the amount of pot-holing action (which I have shown to form an important feature of the erosion at Semna) is far less at Aswan than at Semna, this may be due to the different stages reached in the two cases; there is evidence at Aswan that pot-holing has gone on to a greater extent in the past than is the

* DIODORUS SICULUS, "Hist.," l. i, c. 3; STRABO, "Geog.," l. XVii, C. 1., § 49; POMPONIUS MELA, "De situ orbis," l. i, c. q.; SENECA, "Nat Quæst," l. iV, C. 2.

case now. The comparison labours, indeed, only under that indefiniteness which characterises any attempt to arrive at precise estimations of the rate of geological changes in the past, and it is not advanced as anything more than a means of arriving at an approximate measure.

Geological changes still going on at the Cataract.—The erosive agencies, which have been shown above to account for the observed changes in the level of the river in recent geological times, are still at work continuing the process of grinding away the obstructions in the path of the Nile, and will continue to do so until the Cataract shall have disappeared. The rate of erosion, though gradually falling off as the obstructions are lessened in magnitude, is doubtless even yet comparable with the average value of 20 centimetres per century suggested by the records at Semna. Channels are slowly being enlarged by the planing action of the abrasive material carried by the river, and to an even greater extent by the boring of countless potholes by the sand-laden eddies. When the pot-holing has proceeded to a certain point, the honeycombed rocks are easily broken up by the rush of waters, aided by joint planes and the disintegrating action of the diurnal changes of temperature. Though the rate of lowering of the Cataract channels is so slow as to be imperceptible even with the niceties of measurement practised in the present day, owing to the great variations in the river-supply at different times, the examination of the actions going on convinces us that the change is none the less sure. The construction of the dam will alter the distribution of the erosive forces, but will rather increase than diminish their total effect. To the south of the dam, the ponding-up of the waters for a part of the year will tend to make the erosion slower, but to the north there will be a correspondingly greater velocity due to the accumulated head, and an increased action due to the artificial division of the stream by the sluices. As evidence of the power of the water in rounding large stones, it may be remarked that some ashlar blocks of granite were left in the bed of the stream below the dam for a few months in 1902; these blocks, which were originally roughly squared and measured about 60 centimetres each way, were completely rounded into boulders by the tumbling about they received from the issuing waters. The first year's working of the dam resulted in the formation of large hollows in the rocky bed of the river down-stream of it; wherever the rock was unsound, it was

rapidly removed by water-action, the great head and consequent high velocity rendering the streams issuing from the sluices powerful enough to move masses weighing many tons. Extensive protection-works were thus rendered necessary; all unsound rock remaining was removed, and the hollows filled up by strong cement masonry laid with extreme care, this masonry being carried up so as to form an apron, sufficiently substantial to resist the heavy impact of the escaping waters, along the down-stream foot of the dam.*

The question of the possible silting-up of the reservoir is one which has given rise to some discussion. Like all lakes, the reservoir will certainly diminish gradually in volume from the accumulation of silt; but the effect is not likely to be serious for a very long period. The flood-waters, which bring down the bulk of the Nile silt, pass practically unobstructed through the dam, and the waters are only stored at the time of year when they are relatively clear. Some silt will be deposited, without doubt; but the next flood will scour out the bulk of such deposit, and probably leave the channels in practically their former state. Sandbanks accumulate to a great extent in the reaches between the first and the second Cataracts; but it is doubtful if these affect the volume of the reservoir at all, since erosion of the banks is going on at other places in a way which suggests practically a balance. The effect of the sandbanks on navigation is entirely a separate question from the capacity of the reservoir; a stretch of river a kilometre wide and 3 metres deep may be far more difficult of navigation than one 500 metres wide of double the depth; and still the volume is the same.

The case is otherwise where the distribution of the water is altered by canals or solid artificial obstructions in the stream, and in such cases the greatest caution is often necessary to prevent an accumulation of silt in what are naturally clean channels. An instance occurred in connection with the new lock at the Bab Hemedai, which, when closed during the flood of 1903, so blocked the river as to cause a large deposit below it; after passing the obstruction the silt-laden waters found their velocity suddenly lowered, and in consequence dropped a part of their burden and formed at the northern mouth of the lock a sandbank which had to be removed by dredging.

* See Sir William Garstin, Public Works Ministry Report, 1905, p. 72.

Even near the town of Aswan itself a slow change is going on in the river. A comparison of the results of the recent survey with the map made by Napoleon's Expedition in 1798 will show that a perceptible erosion of the west bank opposite Elephantine has taken place within the last century; and confirmation of this is apparent in the fact that not only is there a huge sandbank on the east shore laid dry during the greater part of the year, but in low stages of the river the whole eastern channel has been left dry, so that it has been possible to walk across from Aswan to Elephantine. Such changes as this are a powerful argument in leading us to prefer actual discharge measurements to gauge-readings over long periods in estimating the discharge of the river.

If we turn now from the river to the desert, we find no less certain evidences of slow, but continuous and sure, present-day change. Every day's variation of temperature adds its quota of disintegrating action on the granite rocks; blocks are split asunder, and crystals of felspar and quartz are broken into sand and slowly removed by gravity and wind. Each one of the rain-storms which occur at about yearly intervals contributes its aid in the transport of broken-down material and in the solution of alkaline salts. Every sand-storm does its part in grinding away exposed surfaces of the rocks, even the hardest; there are some aplites south of the dam on the east bank, the exposed blocks of which show superficially a mere skeleton of quartz, from which all the felspar has been removed by the sandblast. There is, in fact, nothing which is more strongly borne in upon a geologist examining the deserts of Egypt than the potency of small present-day forces to produce by their long-continued action great effects of earth sculpture. Though tectonic changes have conditioned the main features of the desert hills, and though a different climate with heavier rainfall in the past appears necessary to explain the primary formation of the great wadies, yet the whole of the details of the surface-sculpture present nothing more than can be accounted for by agencies still at work acting for a few thousand or tens of thousands of years. Features which at first sight may appear to require some exceptional influence for their explanation, may in the light gained from a study of the effects of the long-continued action of every-day forces, be seen to be but the natural consequence of these latter. As an instance of this, not entirely unconnected with the cataract district, reference may be

made to the huge cracks on Jebel Garra, 34 kilometres west of the Cataract. It seemed at the time when that hill was first examined that the opening of these great clefts could only be accounted for by earthquake action; * but subsequent observation of similar though smaller disturbances at other points has inclined the writer to the belief that the diurnal temperature-range is a sufficient explanation for the facts observed. Thirty-six thousand times in a century the rock has gone through a cycle of expansion and contraction; a crack once started at the surface, the successive slight opening and closing of it would soon deepen it, and ultimately cut right through the thick bed, leaving a great detached mass of limestone on a more or less sloping stratum of clays. Then the continued operation of expansion and contraction of this detached mass would cause it, under the influence of gravitation, to move slowly away from its parent rock in the direction of least resistance, in the same way as that by which Canon Moseley endeavoured to account for the motion of glaciers.† The cleft would thus slowly widen, and the masses occupy at length the positions in which they are now seen.

I have calculated that a block of limestone 10 metres in length subject to an average diurnal change of only 1° C.,‡ would in this manner creep through a distance of a metre in fifty-five years. In the case of sandstone-masses, the movement would be at last twice as rapid, owing to their greater co-efficient of expansion. Such considerations go a long way to account for the peculiarities of certain khors and wadies, the heads of which often form amphitheatres in positions where the smallness of the area drained forbids the supposition that their present form is due entirely to water-action.

* Ball, "Report on Jebel Garra and the Oasis of Kurkur," Cairo, 1902, p. 31.

† Prestwich, "Geology," Vol. 1, p. 181.

‡ The daily temperature-change at the surface may be as much as 50° C. in summer; the average of 1° C. is assumed for the entire mass.

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